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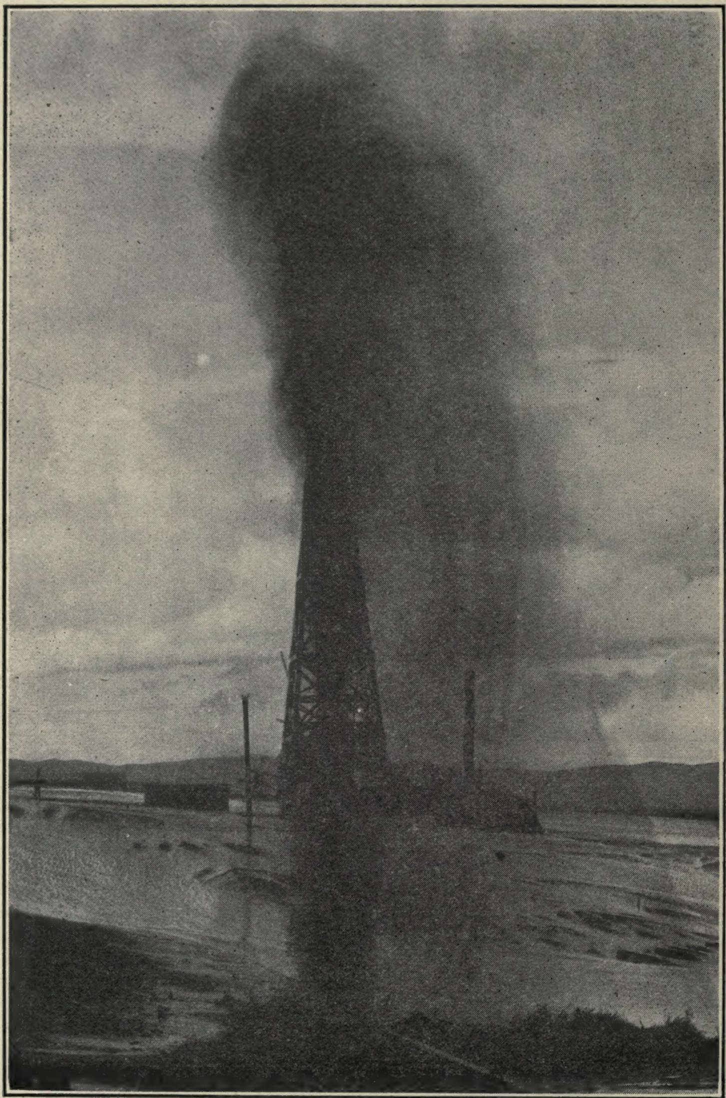

THE FAMOUS LAKEVIEW GUSHER, KERN COUNTY, CALIFORNIA

OIL PRODUCTION METHODS

BY

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With a Chapter on ACCOUNTING SYSTEMS

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PREFACE

The problems associated with the production of petroleum lie in that middle ground where the geologist, engineer and driller meet. It is anticipated that the latter class, the men who have come up 'from the derrick floor,' will find little that is new in this book. It has been prepared in response to the demand for a work describing, in a manner that may be understood by the layman, how wells are drilled and oil produced. The subject is too exhaustive to be covered fully in a single volume of this size, and if the authors have described more particularly the methods of the Pacific Coast fields they feel warranted in so doing from the statements of travelers that California practice embodies the most advanced methods in the industry. The authors are indebted to various associates for prompt responses to demands for assistance and wish to express their thanks to all of these, especially to Mr. H. H. Hillman, of the California National Supply Company, Mr. W. O. Todd and Mr. T. S. Kingston, to whom is due much of whatever value this book may have.

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THE DISTRIBUTION, PROPERTIES AND USES OF PETROLEUM.

AMONG the first historic records of petroleum is that of its use on the walls of Babylon and Ninevah about 2000 B. C. Pliny describes the burning of oil in lamps in the time of Nero, and for ages the seepages of crude oil have been drawn on and used by the people of Persia, Arabia, China and India.

In the United States, crude oil was first secured early in the Nineteenth Century as a by-product in connection with brine wells, but it was not until 1859 that Colonel Drake drilled the first well put down expressly for oil, near Titusville, Pennsylvania. This led to the development of the Appalachian field and since then the search for petroleum and the development of new fields has spread over the continent, under the stimulus of the growth in variety and extent of internal combustion engines, until now the oil and gas production of the United States is greater than that of any other country, and has become one of its most valuable mineral resources. The more important fields are those of the Appalachian district; western Ohio, Indiana and Illinois; southern Kansas and Oklahoma; the Gulf fields of Texas; and the California fields along the coast range. Alaska, Colorado, Michigan, Utah and Wyoming produce small quantities; and Utah and Wyoming especially give promise of a large prospective production.

In the United States the customary unit of volume for measuring petroleum is the barrel of 42 gallons, each gallon containing 231 cubic inches. Other countries measure it more commonly by weight, the English expressing it in tons and the Russians in poods, of approximately 36 pounds. The following conversion table gives the approximate relative values:

61.05 poods = 1 metric ton crude = 7.1905 barrels
8.33 " crude = 1 U. S. barrel of 42 gallons
8 " illuminating oil = 1 U. S. " " " "
8.18 " lubricating oil = 1 U. S. " " " "
9 " residuum = 1 U. S. " " " "
1 pood = 36.112 pounds

The simplest method of boring a well has been that of turning an auger into the ground and this has, no doubt, been extensively used

Production of Petroleum in the United States from

Year.	Pennsylvania and New York.	Ohio.	West Virginia.	California.	Kentucky and Tennessee.	Colorado.	Indiana.	Illinois.
1859	2,000							
1860	500,000							
1861	2,113,609							
1862	3,056,690							
1863	2,611,309							
1864	2,116,109							
1865	2,497,700							
1866	3,597,700							
1867	3,347,300							
1868	3,646,117							
1869	4,215,000							
1870	5,260,745							
1871	5,205,234							
1872	6,293,194							
1873	9,893,786							
1874	10,926,945							
1875	8,787,514							
1876	8,968,906	31,763	120,000	12,000				
1877	13,135,475	29,888	172,000	13,000				
1878	15,163,462	38,179	180,000	15,227				
1879	19,685,176	29,112	180,000	19,858				
1880	26,027,631	38,940	179,000	40,552				
1881	27,376,509	33,867	151,000	99,862				
1882	30,053,500	39,761	128,000	128,636				
1883	23,128,389	47,632	126,000	142,857	4,755			
1884	23,772,209	90,081	90,000	262,000	4,148			
1885	20,776,041	661,580	91,000	325,000	5,164			
1886	25,798,000	1,782,970	102,000	377,145	4,726			
1887	22,356,193	5,022,632	145,000	678,572	4,791	76,295		
1888	16,488,668	10,010,868	119,448	690,333	5,096	297,612		
1889	21,487,435	12,471,466	544,113	303,220	5,400	316,476	33,375	1,460
1890	28,458,208	16,124,656	492,578	307,360	6,000	368,842	63,496	900
1891	33,009,236	17,740,301	2,406,218	323,600	9,000	665,482	136,634	675
1892	28,422,377	16,362,921	3,810,086	385,049	6,500	824,000	698,068	521
1893	20,314,513	16,249,769	8,445,412	470,179	3,000	594,390	2,335,293	400
1894	19,019,990	16,792,154	8,577,624	705,969	1,500	515,746	3,688,666	300
1895	19,144,390	19,545,233	8,120,125	1,208,482	1,500	438,232	4,386,132	200
1896	20,584,421	23,941,169	10,019,770	1,252,777	1,680	361,450	4,680,732	250
1897	19,262,066	21,560,515	13,090,045	1,903,411	322	384,934	4,122,356	500
1898	15,948,464	18,738,708	13,615,101	2,257,207	5,568	444,383	3,730,907	360
1899	14,374,512	21,142,108	13,910,630	2,642,095	18,280	390,278	3,848,182	360
1900	14,559,127	22,362,730	16,195,675	4,324,484	62,259	317,385	4,874,392	200
1901	13,831,996	21,648,083	14,177,126	8,786,330	137,259	460,520	5,757,086	250
1902	13,183,610	21,014,231	13,513,345	13,984,268	185,331	396,901	7,480,896	200
1903	12,518,134	20,480,286	12,899,395	24,382,472	554,286	483,925	9,186,411	
1904	12,239,026	18,876,631	12,644,686	29,649,434	998,284	501,763	11,339,124	
1905	11,554,777	16,346,660	11,578,110	33,427,473	1,217,337	376,238	10,964,247	181,084
1906	11,500,410	14,787,763	10,120,935	33,098,598	1,213,548	327,582	7,673,477	4,397,050
1907	11,211,606	12,207,448	9,095,296	39,748,375	820,844	331,851	5,128,037	24,281,973
1908	10,584,453	10,858,797	9,523,176	44,854,737	[a] 727,767	379,653	3,283,629	33,686,238
1909	10,434,300	10,632,793	10,745,092	55,471,601	[a] 639,016	310,861	2,296,086	30,898,339
1910	9,848,500	9,916,370	11,753,071	73,010,560	[a] 468,774	239,794	2,159,725	33,143,362
1911	9,200,673	8,817,112	9,795,464	81,134,391	[a] 472,458	226,926	1,695,289	31,317,038
Total	727,493,335	406,475,177	226,856,521	456,437,114	7,584,593	10,031,519	99,562,240	157,911,660

[a] No production in Tennessee recorded.

*From *U. S. Geological Survey*, Mineral Resources of U. S., for 1911.

for ages for obtaining water, and is still occasionally employed in some sections for this purpose. The drilling of water-wells preceded that of wells expressly for oil, and in an old Dominican convent garden in France a deep well has flowed continuously since 1126. When rigid iron pipe had become known, driven wells were put down by pointing the end of a piece of pipe, boring small holes near the pointed end and then driving this pipe down by means of a sledge or drop hammer.

1859 to 1911 Inclusive, in Barrels of 42 Gallons.*

Year.	Kansas.	Texas.	Missouri.	Oklahoma.	Wyoming.	Louisiana.	United States.	Total value.
1859							2,000	$32,000
1860							500,000	4,800,000
1861							2,113,609	1,035,668
1862							3,056,690	3,209,525
1863							2,611,309	8,225,663
1864							2,116,109	20,896,576
1865							2,497,700	16,459,853
1866							3,597,700	13,455,398
1867							3,347,300	8,066,993
1868							3,646,117	13,217,174
1869							4,215,000	23,730,450
1870							5,260,745	20,503,754
1871							5,205,234	22,591,180
1872							6,293,194	21,440,503
1873							9,893,786	18,100,464
1874							10,926,945	12,647,527
1875							8,787,514	7,368,133
1876							9,132,669	22,982,822
1877							13,350,363	31,788,566
1878							15,396,868	18,044,520
1879							19,914,146	17,210,708
1880							26,286,123	24,600,638
1881							27,661,238	23,512,051
1882							30,349,897	23,631,165
1883							23,449,633	25,740,252
1884							24,218,438	20,476,924
1885							21,858,785	19,193,694
1886							28,064,841	20,028,457
1887							28,283,483	18,856,606
1888							27,612,025	17,950,353
1889	500	48	20				35,163,513	26,963,340
1890	1,200	54	278				45,823,572	35,365,105
1891	1,400	54	25	30			54,292,655	30,526,553
1892	5,000	45	10	80			50,514,657	25,906,463
1893	18,000	50	50	10			48,431,066	28,932,326
1894	40,000	60	8	130	2,369		49,344,516	35,522,095
1895	44,430	50	10	37	3,455		52,892,276	57,691,279
1896	113,571	1,450	43	170	2,878		60,960,361	58,518,709
1897	81,098	65,975	19	625	3,650		60,475,516	40,929,611
1898	71,980	546,070	10		5,475		55,364,233	44,193,359
1899	69,700	669,013	132		5,560		57,070,850	64,603,904
1900	74,714	836,039	[a] 1,602	6,472	5,450		63,620,529	75,752,691
1901	179,151	4,393,658	[b] 2,335	10,000	5,400		69,389,194	66,417,335
1902	331,749	18,083,658	[a] 757	37,100	6,253	548,617	88,766,916	71,178,910
1903	932,214	17,955,572	[a] 3,000	138,911	8,960	917,771	100,461,337	94,694,050
1904	4,250,779	22,241,413	[a] 2,572	1,366,748	11,542	2,958,958	117,080,960	101,175,455
1905	[c] 12,013,495	28,136,189	[a] 3,100	([d])	8,454	8,910,416	134,717,580	84,157,399
1906	[c] 21,718,648	12,567,897	[a] 3,500	([d])	[e] 7,000	9,077,528	126,493,936	92,444,735
1907	2,409,521	12,322,696	[a] 4,000	43,524,128	[f] 9,339	5,000,221	166,095,335	120,106,749
1908	1,801,781	11,206,464	[a] 15,246	45,798,765	[f] 17,775	5,788,874	178,527,355	129,079,184
1909	1,263,764	9,534,467	[a] 5,750	47,859,218	[f] 20,056	3,059,531	183,170,874	128,328,487
1910	1,128,668	8,899,266	[a] 3,615	52,028,718	[f] 115,430	6,841,395	209,557,248	127,899,688
1911	1,278,819	9,526,474	[a] 7,995	56,069,637	[f] 186,695	10,720,420	220,449,391	134,044,752
Total	47,830,182	156,986,662	54,077	246,840,779	425,741	53,823,731	2,598,313,351	2,174,229,796

a Includes the production of Michigan.
b Includes production of Michigan and small production in Oklahoma.
c Includes production of Oklahoma.
d Included with Kansas.
e Estimated.
f Includes the production of Utah.

World's production of crude petroleum, 1906–1911, by countries, in barrels and metric tons.

Country.	1907	1908	1909	1910	1911			
					Rank.	Barrels.	Metric tons.	Per-cent of total production.
United States........	166,095,335	178,527,355	183,170,874	209,557,248	1	220,449,391	29,393,252	63.80
Russia................	61,850,734	62,186,447	65,970,350	70,336,574	2	66,183,691	9,066,259	19.16
Mexico................	1,000,000	3,481,410	2,488,742	3,332,807	3	14,051,643	1,873,552	4.07
Dutch East Indies...	9,982,597	10,283,357	11,041,852	11,030,620	4	12,172,949	1,670,668	3.52
Roumania............	8,118,207	8,252,157	9,327,278	9,723,806	5	11,101,878	1,544,072	3.21
Galicia................	8,455,841	12,612,295	14,932,799	12,673,688	6	10,485,726	1,458,275	3.04
India..................	4,344,162	5,047,038	6,676,517	6,137,990	7	6,451,203	897,184	1.87
Japan..................	2,010,639	2,070,145	1,889,563	1,930,661	8	1,658,903	221,187	.48
Peru....................	756,226	1,011,180	1,316,118	1,330,105	9	1,398,036	186,405	.40
Germany.............	756,631	1,009,278	1,018,837	1,032,522	10	995,764	140,000	.29
Canada................	788,872	527,987	420,755	315,895	11	291,096	38,813	.08
Italy....................	59,875	50,966	42,388	42,388	12	a 71,905	10,000	.02
Other..................	a 30,000	a 30,000	a 30,000	a 30,000	....	a 200,000	26,667	.06
Total........ ..	264,249,119	285,089,615	298,326,073	327,474,304	....	345,512,185	46,526,334	100.00

Such wells were found to be successful only for comparatively shallow holes and loose formations.

The churn, or free-falling tool method is thought to have originated with the Chinese centuries ago in their search for water in the arid districts. In this system, falling tools, suspended from the surface, drill the hole by impact and churning motion; and adaptations and improvements of this method are used in drilling the large proportion of wells sunk today.

The first American churn drill made use of a spring pole supported on a forked upright. Suspended from the end of this pole was a 'string' of solid wooden rods which were screwed together, and into the lowest of which was screwed the cutting tool. It was operated by several men who pulled the end of the pole down quickly so that the drill would strike a blow at the bottom of the hole; the spring of the pole would then lift the drill, so that it might be pulled down again. In order to clean out the cuttings, the rods would be raised and unscrewed one by one, the drilling tool removed, and a sand pump put in its place. This was a long tube with a flapper bottom opening inward, which allowed the sand to work up into the tube, when the latter was lowered on bottom, and held it there while the pump was being pulled from the well.

This led to the Canadian 'pole-tool' system that has seen extensive use till recent years, especially, as its name implies, in Canada. In this the spring pole was replaced with a walking beam. Steam was used for motive power, and the poles suspended from a 50-ft. derrick while being run in and pulled from the well. The poles, of wood and from 1⅞ to 3 in. diameter, usually consist of two rods

spliced end-wise with iron straps and rivets, making a total length of 35 feet. At one end a band is riveted to the wood and its end is a threaded pin; the other end has a box into which the pin of the next lower rod is screwed. The walking-beam supplies the drilling motion and a chisel-point bit on the end of a 'string' of tools, similar to those in common use, does the cutting. While drilling, the string of poles is suspended from a chain which winds several times around a pipe that projects beyond the end of the walking beam. The chain runs along the top of the walking beam to a ratcheting device known as the 'slipper out' by means of which the driller is enabled to let out the chain when he wishes to lower the string of poles a few inches in order to make the bit strike solid ground on bottom. As in the spring pole method, the cuttings in the hole are brought out by means of a sand pump or bailer, run in and out of the hole on the bottom of the string of poles. This method has been quite successful in drilling some fairly deep wells, but is seldom used now.

The necessity for reaching greater depths than could be drilled with the spring-pole or Canadian pole-tools called for heavier tools and improved methods, and so there came about a gradual evolution to the use of horse power and steam; from the spring pole to the walking beam with its rigidity and positive motion; from rods screwed together to manila rope and wire cables. At the same time were developed many special drilling and fishing tools, and the greatest single improvement of all, the use of casing or pipe for holding back caving ground that tends to fall in and fill the hole, and for excluding from the oil-sand the water from overlying strata.

Much of this growth has occurred as different requirements of the various new fields were encountered, so that while the basic methods of drilling along the lines either of the standard tools or the rotary are followed everywhere, yet local conditions and the inherent inventive ability of the oil operative have resulted in any number of special applications of these methods, devised to overcome the specific obstacles encountered.

A volume of this kind cannot include descriptions of all the ingenious schemes at the command of the old driller experienced in many fields. At best, few branches of engineering carry the hazard and chance that accompany drilling for oil. A little carelessness, an unavoidable accident or defect in tools or equipment may result

in plugging a hole, with the loss of months of work. A plugged hole has slight salvage value and the need for *keeping* out of trouble, rather than of *getting* out, is constantly before the oil man; and while

Fig 5. STAR PORTABLE DRILLING MACHINE WITH MAST IN PLACE

fishing jobs are inevitable, yet care and proper precautionary steps are features of exceptional value in this work.

The two methods of drilling most commonly employed are known as the standard, or cable-tool method, and the hydraulic, or

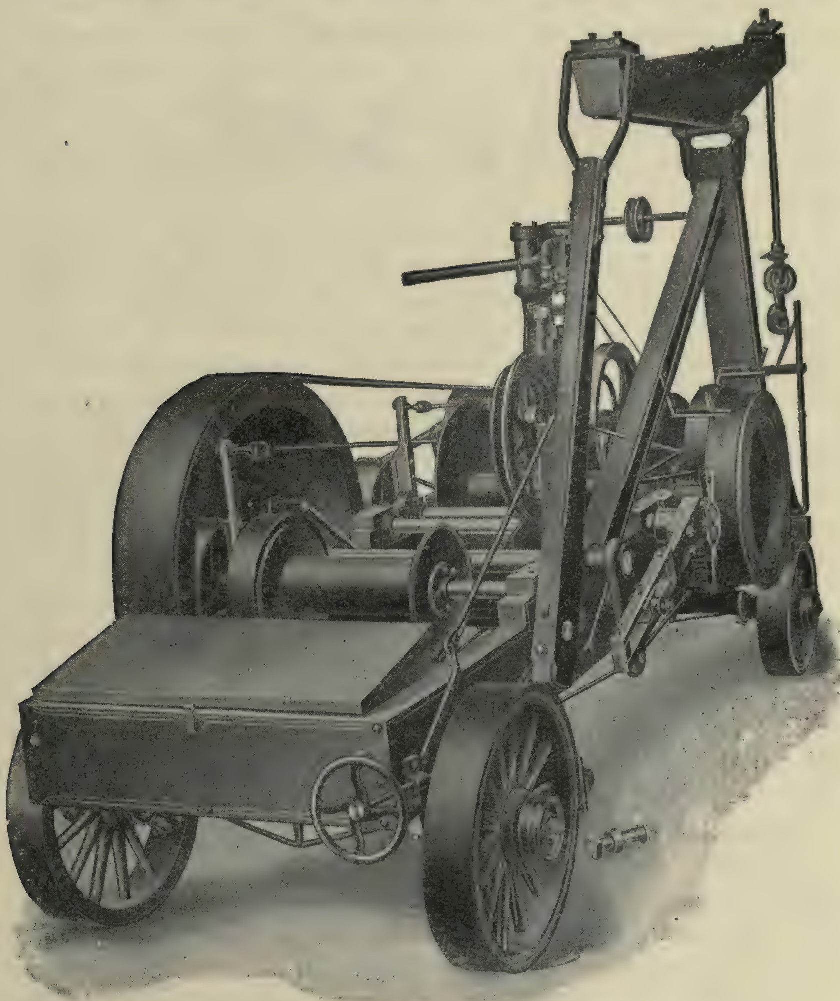


Fig. 6. STAR PORTABLE DRILLING MACHINE

rotary method. The former employs a walking beam to churn the hole by an up-and-down motion imparted to tools suspended from a line connected with the end of the beam. When the hole has been advanced several feet, the cutting tools are withdrawn

and a bailer, or sand pump, is run in on the end of another line, for the purpose of removing the cuttings. The rotary method of drilling is a cutting process by which a suitable bit, attached to the end of a column of pipe that is turned by machinery at the surface, is made to scrape away the bottom of the hole. Thin mud is pumped down inside the pipe and through an opening at the bottom, from where it returns to the surface on the outside of the pipe, bringing with it the drill cuttings. The process is practically continuous except for the necessity of pulling the pipe from the well when the cutting-bit has become dull and must be replaced with a sharp one.

Each of these methods is successful when used for drilling in ground to which it is adapted. In general, the cable-tool method is preferred where the series of strata to be pierced is hard and the severe impact of the walking-beam motion is needed to churn the hole. In soft and loose material, the rotary method is usually superior, and while it entails a greater expense for labor, fuel, and maintenance of machinery, yet the speed it often attains and other advantages described in detail in the chapter devoted to drilling, often warrant the added expense from the standpoint of commercial feasibility. It is rarely, however, except in the Gulf Coast districts, that it is employed in drilling wildcat wells.

It should be noted here that the term 'wildcat' does not possess the unsavory meaning associated with it in the mining world, where it suggests dubious financial operations rather than progressive mining activity. In the oil fields, a 'wildcat' well is a prospect or test well, drilled sufficiently far from proved territory to raise the question as to whether or not oil will be found. Much wildcatting is carried on by many of the old substantial companies.

Properties and Uses. Petroleum is a liquid belonging to a series of hydro-carbon compounds of complex chemical composition ranging from the gaseous to the solid state, namely, natural gas, petroleum, mineral tar, and asphalt. These pass by insensible gradations from one to the other with no strict line of demarcation between them; and among the petroleums, wells only a short distance apart will frequently show remarkable differences in composition and gravity. In the United States, the oil which has a paraffin base generally occurs east of the Mississippi while west of it usually is found the heavier oils with an asphalt base.

Within the limits of individual fields, the value of petroleum is generally rated according to its weight, or specific gravity, the

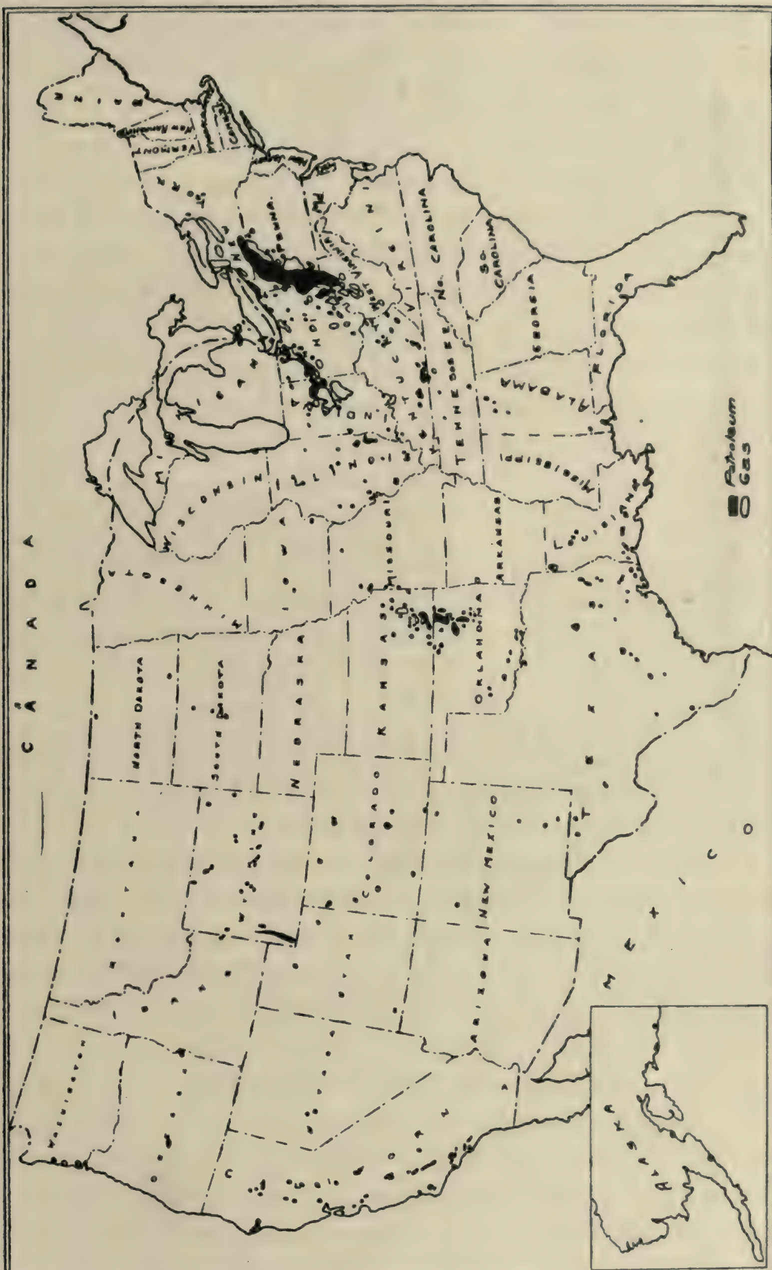


Fig. 7. MAP SHOWING POSITION OF KNOWN PETROLEUM AND GAS DEPOSITS IN THE UNITED STATES.
From U. S. Geologcal Survey

greater value going with the lighter oils that contain a higher percentage of the more valuable products. By specific gravity is meant the relation in weight between any given volume of oil at 60° F. and that of an equal volume of pure water at 39.2° F. This is generally designated in oil field practice according to the Beaumé scale, in which the weight is represented by degrees, the higher numbers being those of the lighter oils, and 10° Beaumé the equivalent of water. The gravity is determined by the use of a Beaumé hydrometer (Fig. 8), a glass column which, when immersed in oil, sinks to a depth dependent on the density of the oil. A scale on the glass shows the depth of immersion and gives a direct reading of the gravity, except for a correction that must be applied if the temperature of the oil is greater or less than 60° F. A thermometer is generally combined with, and made a part of, the hydrometer. The temperature correction varies with oils of different gravities and published tables of correction must be used when precision is desired, but for ordinary oil field work a reduction of 1° in gravity for every 20° of temperature above 60° F. is sufficiently close for oils around 18° Beaumé. With 25° Beaumé oil the correction is 1° Beaumé for every 16° above 60° F., with corresponding additions of course when the temperature of the oil is below 60° F.

Fig. 8
HYDROMETER AND THERMOMETER COMBINED

Degrees Beaumé may be converted to specific gravity by adding 130 to the Beaumé degrees and dividing this by 140. Thus, if the hydrometer reading, when corrected for temperature, is 28.2° Beaumé the specific gravity is obtained by adding 130, making 158.2, and dividing this sum by 140, or 0.885 as the specific gravity.

Specific Gravities of Typical Oils.

State.	Specific Gravity.	Gravity Beaumé.
Pennsylvania	0.801 — 0.817	46.2 — 42.6
Ohio	0.816 — 0.860	42.8 — 32.5
Kansas	0.835 — 1.000	38.8 — 10.0
West Virginia	0.841 — 0.873	37.6 — 30.0
Beaumont, Texas	0.904 — 0.925	24.8 — 31.1
Wyoming	0.912 — 0.945	23.3 — 11.9
California	0.920 — 0.873	30.0 — 12.3

B°	Sp. Gr.	Weight per Gallon	Weight per Barrel	Weight per Cu. Ft	B°	Sp. Gr.	Weight per Gallon	Weight per Barrel	Weight per Cu. Ft.
10	1.0000	8.328	349.79	62.301	45	.8000	6.663	279.83	49.841
11	.9929	8.269	347.31	61.859	46	.7955	6.623	278.26	49.560
12	.9859	8.211	344.86	61.422	47	.7910	6.588	276.68	49.280
13	.9790	8.153	342.45	60.993	48	.7865	6.550	275.11	48.999
14	9722	8.097	340.07	60.569	49	.7821	6.514	273.57	48.726
15	.9655	8.041	337.72	60.152	50	.7778	6.478	272.07	48.458
16	.9589	7.986	335.42	59.740	51	.7735	6.442	270.56	48.189
17	.9524	7.932	333.14	59.335	52	.7692	6.406	269.06	47.922
18	.9459	7.878	330.87	58.931	53	.7650	6.371	267.59	47.660
19	.9396	7.825	328.67	58.538	54	.7609	6.337	266.16	47.405
20	.9333	7.773	326.46	58.145	55	.7568	6.303	264.72	47.149
21	9272	7.722	324.33	57.765	56	.7527	6.269	263.29	46.894
22	.9211	7.671	322.19	57.385	57	.7487	6.235	261.89	46.644
23	.9150	7.620	320.06	57.005	58	.7447	6.202	260.49	46.395
24	.9091	7.571	317.99	56.637	59	.7407	6.169	259.09	46.146
25	.9032	7.522	315.93	56.270	60	.7368	6.136	257.73	45.903
26	.8974	7.474	313.90	55909	61	.7330	6.105	256.40	45.667
27	.8917	7.426	311.91	55.554	62	.7292	6.073	255.07	45.429
28	.8861	7 379	309.95	55.205	63	.7254	6.041	253.74	45.193
29	.8805	7 339	307.99	54.856	64	.7216	6.009	252.41	44.956
30	.8750	7.287	306.07	54.513	65	.7179	5.979	251.12	44.726
31	.8696	7.242	304.18	54.177	66	.7143	5.949	249.86	44.502
32	.8642	7.197	302.29	53.840	67	.7107	5.919	248.59	44.277
33	.8589	7.153	300.44	53.510	68	.7071	5.889	247.34	44.053
34	.8537	7.110	298.62	53.186	69	.7035	5.859	246.08	43.829
35	.8485	7.066	296.80	52.862	70	.7000	5.829	244.85	43.611
36	.8434	7.024	295.02	52.545	71	.6965	5.801	243.63	43.393
37	.8383	6.982	293.23	52.227	72	.6931	5.772	242.44	43.181
38	.8333	6.940	291.48	51.915	73	.6897	5.744	241.25	42.969
39	.8284	6.899	289.77	51.610	74	.6863	5.716	240.06	42.757
40	.8235	6.858	288.05	51.305	75	.6829	5.687	238.87	42.545
41	.8187	6.818	286.38	51.006	76	.6796	5.660	237.72	42.339
42	.8140	6.779	284.73	50.713	77	.6763	5.632	236.36	42.134
43	.8092	6.739	283.05	50.414	78	.6731	5.606	235.45	41.935
44	.8046	6.701	281.44	50.127	79	.6699	5.579	234.33	41.735

Fig. 9. TABLE SHOWING RELATIVE BEAUME AND SPECIFIC GRAVITY OF CRUDE OILS*

**Western Engineering,* April, 1913.

The physical qualities of petroleum have a wide range. It varies in color from colorless to yellow, green and black, dark brown and greenish brown predominating. Its consistency may be very thin and flowing, or thick and viscous to the point where it must be heated to make it flow. It solidifies at from 82° F. in

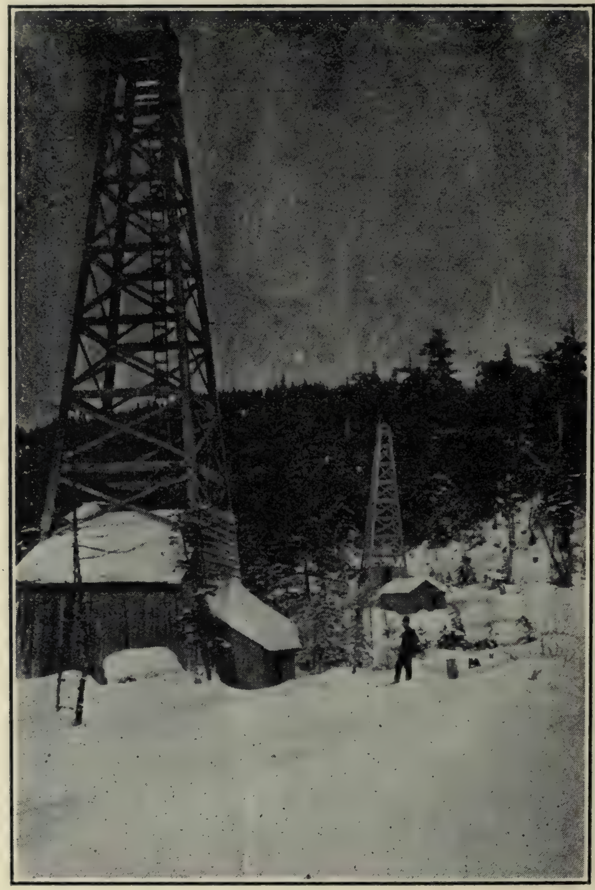


Fig. 10. OIL WELLS AT KATALLA, ALASKA

some Burmah oils to zero in some Italian oils. The flash point, which is the lowest temperature at which inflammable vapors are given off, ranges with different oils from zero to 370° F. The boiling point also has a wide range, from 180° F. to 338° F.

The more important oils that go to make up its complex mixture, and which are separated by distillation, are gasoline, benzine,

distillates and kerosene, heavy naphthas and residuum. Paraffin base petroleums contain greater quantities of the lighter oils, illuminants and lubricants, and are accordingly more valuable than those with an asphalt base. The latter are chiefly used for heavy fuel after such lighter constituents as they contain have been recovered.

While of course the greater portion of petroleum produced finds its way into use either for fuel or lubrication, the fact should not be overlooked that the uses to which it and its products can be applied are constantly extending. Several ingenious lamps are made in which the vapors of either gasoline or ordinary kerosene are burned in incandescent mantles. Oil supplies the illuminating element in the manufacture of water gas. Paraffin wax, vaseline, furniture polish and many other by-products from different petroleums, obtained by various methods of refining, are used commercially and in the arts. Its use for water-proofing, mosquito prevention and as an insecticide are well known.

The Elmore process of ore treatment makes use of the affinity of oil for metals to treat finely crushed ore in an emulsion of water and oil in such a way as to cause the oil to form a film about the metallic particles, bringing these to the surface while the non-metallic waste is drawn off below. The commercial development of the Diesel engine during the past few years, by which crude oil may be applied directly in internal combustion engines, gives promise of extensive use for petroleum for that purpose in the near future. An idea of the wide range of uses to which it is applied may be obtained from the statement that no less than 312 separate products are marketed from eastern crude oil, and the number derived from California crude oil is said now to be over two hundred.

CHAPTER II.

GEOLOGY.

Geology, as it finds application in the petroleum industry, concerns itself chiefly with the study of sedimentary rocks and their structure, or that branch known as stratigraphy. Igneous rocks, which are of volcanic origin, and metamorphic rocks, formed by the action of pressure and heat on either igneous or sedimentary rocks, are never the primary source of oil, and such oil as has in rare instances been found in them has escaped thereto from the sedimentary formations.

In the study of the earth's form we find many agencies at work on it, constantly altering its configuration. Rains, winds, and frost are changing the surface by tearing down material at one point and transporting it to another, doing this slowly but with a great cumulative effect throughout the centuries in which geological time is measured. Rivers bring down immense quantities of sand and silt, depositing these in lakes, lagoons, and the sea. Waves are breaking into the shore line and washing material back under the water, to be deposited there again. Through these and the many other influences at work new bodies of slightly consolidated sediments are constantly being deposited under water, and in this way are formed the stratified rocks, as differentiated from the igneous, which are of volcanic origin and have been fused. In the latter class are the granites, porphyries, and other crystallines more generally associated with metallic ore deposits. Heat, and often great pressure, have been important factors in the process of their formation and they are most readily recognized by their compactness and crystalline structure.

The stratified rocks, which include the sandstones, limestones, shales, and clays are more apt to be loose and friable and are characterized by their division into parallel sheet-like masses known as strata. About nine-tenths of the surface, as well as the entire sea-bottom of course, consist of stratified rocks, the former having been brought to their present position through the elevation of

what at one time lay under water. Much of the history of the surface of the earth in past ages has been learned from the study of the stratified rocks. Fossils, which are the remains of either animal or vegetable matter existing at the time the sedimentary strata were deposited, throw light on the life of the time and are valuable aids in correlating and identifying measures in the field.

These measures are found to have an historical sequence in the order of their deposition, and in some districts their chronological relations have been worked out in great detail. The greater periods of geologic time are known as Eras; these are divided into a number of Periods, the Periods into Epochs and the latter further subdivided into stages represented in the rocks by Formations. It should be noted that the kind of rock and its appearance, whether sandstone, shale or limestone, has no direct connection with the age, inasmuch as different combinations of these are repeated in all Epochs; and oil has been found in the rocks of nearly every Period. In the United States, the eastern oils are obtained from the geologically older measures and those of the southern and western fields from the more recent. Gas shows an equally wide geological distribution.

Classes of Sedimentary Rocks.

The stratified rocks are classed according to the material of which they are chiefly composed such as sand, lime, etc. These classes are then further divided and identified by other characteristics such as color, compactness, size of the individual grains comprising them, and the cementing material occupying the interstices between the grains. The latter is an especially important feature in its effect on the stone as a whole. Sandstone, colored red by a cement of iron oxide which is not soluble in water, is often valuable for building stone, while sandstone with a lime cement would have no value for this purpose because of its eventual disintegration due to the ease with which the limestone washes out. If lime is the cementing material the rock is known as calcareous; it is ferruginous if the cement is one of the iron oxides; siliceous if it is silica; and argillaceous if it is clayey.

Often in the same locality a measure will pass from one class to another by insensible gradations. A shale may be traced along and found to begin to show particles of sand, then gradually a greater and greater sand content until it finally merges into a sandstone, with only a trace, if any, shale remaining in it.

Sands and Sandstones. Sands are the partly unconsolidated bodies while sandstone is the term applied to the same material when in a more compact, solid and hard condition. Both are shallow water deposits and the grains of quartz comprising them vary in size from extremely fine particles to the coarser varieties and to gravel. Since most of the oil produced is obtained from beds of sand, where the oil has accumulated in the space between the grains, it is evident that the porosity of the sand and its capacity for containing oil will have an important bearing on the production to be obtained from a well drilled into it. The amount of oil that comparatively dense sandstones can hold is often surprising; it is estimated that loose sands frequently

Fig. 11. SANDSTONE ENCOUNTERED IN CALIFORNIA OIL FIELDS

contain over 20% by volume of oil, although probably not over three-fourths of this is recoverable.

The variation in texture and porosity of sand beds within short distances no doubt accounts for the noticeable differences in production capacity of wells closely situated, and which to all outward appearances should yield equal amounts of oil. With all other factors equal, it is generally accepted as true that the relative thickness of sands will have a bearing on their productivity, and while this point fails to hold in very many cases, yet it is usually considered distinctly encouraging when a wide body of sand is found to hold the oil rather than a narrow one.

The ideal sand is that in which the grains adhere sufficiently to prevent their loosening and moving, and which, at the same time, is porous enough to permit ready passage of the oil to the opening

through which it is brought to the surface. Too compact a sand may retard the flow of oil towards the opening and so allow only a small amount to reach the point from which it may be recovered. A sand that is too porous is apt to be loose and fall against the pipe, collapsing it. It may fill the inside of the pipe, 'sanding it up', requiring that it be cleaned out and with the disadvantage of increased labor costs in its maintenance as well as the loss of production while it is being cleaned.

In this, as seems to be the case in all matters associated with the development of petroleum, conditions differ in various fields and in

Fig. 12. WELL THROWING OUT SAND

some localities the results of experience have shown that, as expressed by the driller, "The well must make the sand in order to make the oil." Wells, in which the flow of gas and oil has been great enough to keep the loose sand moving along to the surface with the fluids as fast as it reached the pipe, have often developed into immense gushers, in the course of which they would bring up surprising quantities of sand. There is no question but that, under such circumstances, the area from which the oil supply is derived becomes greatly widened, many tributary channels are opened and

the well continues a good producer for a long time, while nearby wells that are sunk later and after the sand has been relieved of its great initial gas-pressure, do not get the benefit of such a strong flow of gas and sand and remain only fair producers.

Beds of sandstone are also the principal type of reservoir for the storage of underground waters, and it should be particularly noted in this connection that, except within narrow limits of local fields, sands have no marked physical characteristics by which they can be described as oil sand, gas sand, or water sand. Much harm has been done and much money needlessly squandered through the belief that a certain form of sand surely contains oil and that some other form

Fig. 13. ACCUMULATION OF SAND AFTER FLOW

of sand may hold only water. Sands are sands, and the only oil sand is a sand containing oil and the only water sand is one holding water. Careful microscopic study of sands is often useful in the detailed study of a local district but the application of data obtained in this way to a wider area cannot be depended upon and is more apt to be misleading and harmful.

Heaving, or running sands, encountered when drilling, are bodies of loose sand usually carrying water, which often give much trouble by reason of their not 'standing up' on the side of the hole but continually falling in and filling it. Tar sands are those containing variable quantities of heavy oil and the term is generally applied to non-productive measures.

Shales and Clays. Shales and clays indicate deep water deposition. They have a finer texture than sand, are more dense and

compact, and are so nearly impervious to the passage of oil that only rarely are they a source of it. However, as will be shown later, they do play an important rôle in the accumulation of bodies of oil and it is seldom that wells are drilled without penetrating wide bodies of these materials. When subjected to the influence of heat and pressure they may be altered to the form of slate, which is also frequently met in drilling. Soft shale and clay are often designated as 'gumbo' by drillers while slate, or any other hard substance that impedes the progress of the drill is known by the broad term of 'shell.' In the various oil fields, different clays and shales become known to have certain features by which they may be distinguished, and the knowledge of these beds and their relation to each other and to the productive measures is often of value as a guide in drilling a new well.

Limestone. Beds of limestone consist of calcium carbonate particles with usually a cement of the same material, although the term limestone is generally applied as well to dolomite, a form in which part of the calcium carbonate is replaced with magnesium carbonate. It occurs often in exceedingly wide bodies, and is the source of petroleum in the Canadian fields of Ontario, in Ohio and Indiana, and is the main productive body at the Spindle Top fields in Texas. Wells drilled in these fields are frequently dynamited with nitroglycerine in order to loosen the formation and extend the zone from which the oil is drawn.

Gravels and Conglomerates. These are composed of rounded pebbles of all sizes with collections of finer material occupying the voids between. Like the sands, they have a shallow water origin and their properties of texture and porosity bear similar relations to the collection and retention of bodies of oil.

Origin of Oil.

The invariable association of gas with oil, although the latter may sometimes form alone, seems to establish the fact that they have the same or a similar origin. Two general classes of theories as to the origin of petroleum have been developed, known as the inorganic theory and the organic theory, and while these have in turn been subjected to many interpretations, by as many theorists, the fundamentals only of each will be given below. The *inorganic theory* has been put forward by chemists and is, in a general sense, that surface waters pass to the heated interior portions of the earth, where they are converted into steam and combine with carbide of iron to form the hydro-carbon products; these are then forced back

to or near the surface by the force of the steam generated. Geological developments, however, fail to substantiate this theory.

The *organic theory* ascribes animal and vegetable matter as the source of petroleum, and holds that this matter has been subjected to a slow distillation while covered so that no air was present. It accords more nearly with the facts of the occurrence of crude oil and is the generally accepted theory. The scattered distribution of oil, its almost invariable association with sedimentary rocks either containing or, closely situated to, fossils, and the fact that ordinary fish oil may be distilled so as to yield a number of the petroleum products, all seem to point towards petroleum having originated from some form of life the remains of which have been subsequently heated without access to air and thereby distilled.

The trend in the more recent discussion of this subject has been in the direction of placing vegetable rather than animal remains as the principal source of the oil.* The immense amount of animal matter that would be required to supply the material and the present day conditions that may be noted in many parts of the world where vegetation accumulates in huge quantities in marshes, lagoons, and swamps are cited as evidence pointing in this direction. This accords also with the fact that oil is usually found in sands and that these are shallow water deposits.

Relation of Rock Structure to the Occurrence of Petroleum.

It is evident that when material has been eroded and transported to where it is to be deposited, the deposition will not be uniform but that the coarser and heavier bodies will sink first, leaving the finer particles in a longer period of suspension. For this reason sands and gravels imply shallow water deposition while the more comminuted materials that form the shales and clays remain in suspension and are transported farther from shore so that they are deposited at greater depths and in more quiet waters. In the course of time these become covered with further depositions, the weight of the overlying strata causes the lower measures to become more compact and rock-like, and there are built up wide bodies of strata horizontally placed, or with only a slight inclination. During this period the shore line may advance and retreat many times, so that what was deep water becomes shallow, resulting in a bed of sand being deposited on top of a layer of clay, and *vice versa* (Figure 14). Eventually the constant effort of the internal forces at work in the

*E. H. C. Craig; 'Oil Finding.'

earth's interior may alter the position of the entire mass, or portions of it, and tangential stresses may distort it by causing it to crinkle and bend into arch-like folds.

The stratified rocks as found exposed on the surface of the earth are rarely horizontal and uniformly continuous, but instead may be tilted, folded, or have portions thrown off and their continuity broken to such an extent that their exact interrelation may be established only by a careful survey over an extended area. Such work becomes more complex through the fact that as soon as strata are elevated above sea level their degradation begins and, as they stand now, only small portions of some remain, the rest having been eroded and carried away.

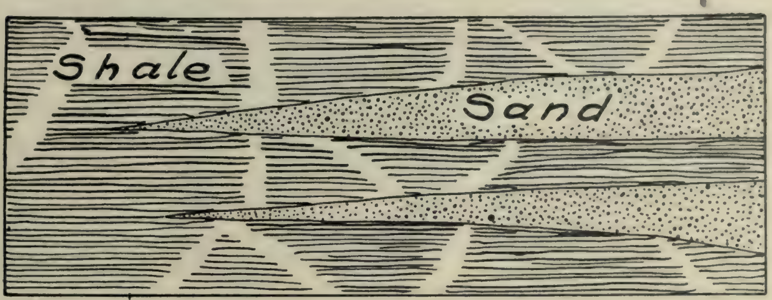


Fig. 14. SAND STRATA OF DIMINISHING THICKNESS

The *dip* of a stratum is the angle between its inclination and a horizontal plane. This is expressed in degrees and in direction—thus 15° N42W. For measuring the dip, several forms of *clinometers* are used, the simplest of which is similar in appearance to an ordinary pocket folding rule with two legs working on a hinge. One leg is placed on the stratum in the direction of its greatest inclination, and the other is swung upwards until it is horizontal as indicated by the bubble in a level which it holds. The angle is then read on a circular scale attached to it. The direction it takes when placed at the maximum inclination is the direction of the dip. Other forms of clinometers, with which compasses are combined, give direct readings of the dip and direction at the same time. As strata often contain minor small waves it is better when taking the dip and a sufficiently wide exposure can be found, to place a board or stick on it, conforming to the general direction and to place the clinometer on the board.

The *strike* is the line of direction taken by strata, or the line that would be formed by the intersection of the strata and a horizontal

plane. This is represented by the line *ad* in Fig. 15. Obviously this is at right angles with the direction of the dip, and when the strata are not bent, it will be a straight line. Should the strata not only dip but bend also, then the strike will be a curve and when the measures have been upturned into a dome-like structure, so that

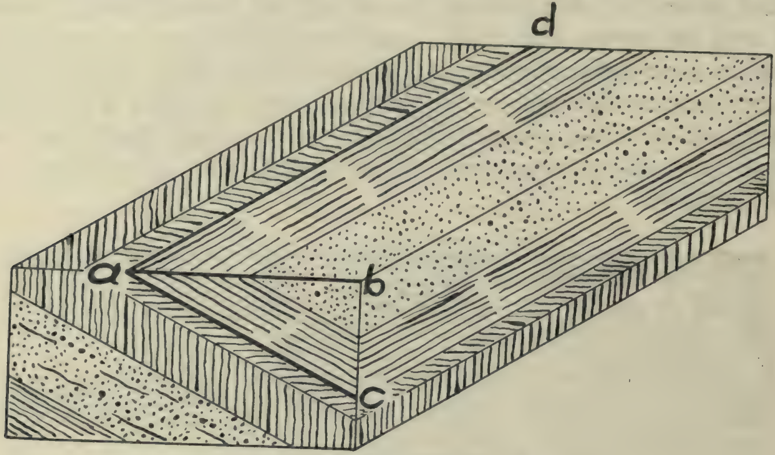


Fig. 15. DIP AND STRIKE OF STRATA

each stratum occupies the position of an inverted bowl, the strike takes the form of the circumference of a circle.

Anticline is the name given to the arch-like position taken by strata when they have been folded. The corresponding position of strata when they are bent down and then up is known as a *syncline*, and frequently the crinkling in the earth's crust that has brought about the folding structure has resulted in a series of wave-like alternating anticlines and synclines (Fig. 16).

Fig. 16. SYNCLINE AND ANTICLINE

Where a series of strata is in an inclined position without the development of folding apparent or nearby, the structural form is known as a *monocline*. A monocline is really only one portion of a broad general fold. The line along the top of an anticline is the *anticlinal axis;* that along the bottom of the syncline is the *synclinal axis*.

The *anticlinal theory*, of I. C. White, relating to oil formation was first brought out in connection with the development of the Appalachian fields and has had a wide application since then in many districts. It holds that, where strata are horizontal the oil and gas are irregularly scattered through the measure containing them, while in folded districts the oil and gas collect at the summits of the anticlines, and the synclines between are apt to be barren or to hold water. Another theory, that of Lesley and Ashburner, assumes porous areas of rock in which the oil has gathered, and is also applicable in some fields.

Aside from theories, however, it is now a well-established fact that practically all petroleum is obtained from sedimentaries and that the major portion is derived from the sands and sandstones, and that these productive measures are usually overlain with a so-called cap rock. The cap rock is an impervious layer, of clay, shale, or some other compact material, which prevents ascension on the part of the gas and oil into higher strata and is especially important in connection with the anticlinal theory.

In connection with the latter, the evidence developed in many fields shows that the fluids confined in a sedimentary measure tend in the course of time to separate according to their respective specific gravities. The gas rises to the topmost point available while the water, if such be present (and salt water is almost invariably associated with petroleum) displaces the oil by reason of its greater weight. Thus there are three fairly well-marked zones, first the gas, then the oil, and finally at the bottom the water. (Fig. 17.) The transition from gas to oil is not as definite and may not be so clearly shown as that from oil to water. In the latter it is not uncommon to trace out within a short distance, along a line of wells which penetrates the oil at greater and greater depths, a gradual change from oil with no water content to that containing a slight and then increasing percentage till finally a well far enough out on the trough of the syncline will be drilled which yields water only and no oil.

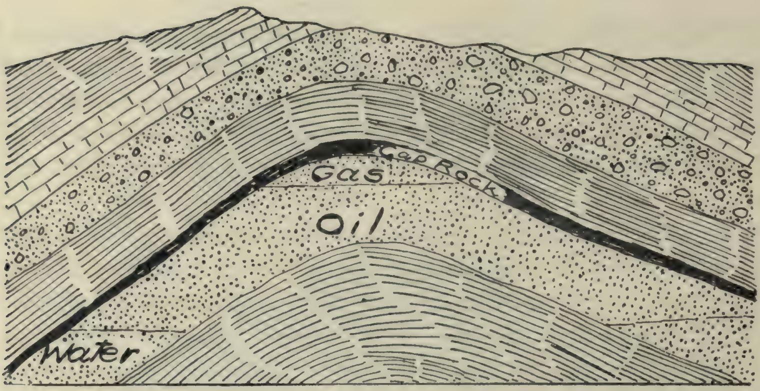
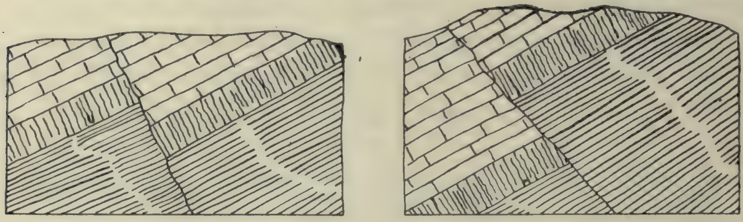


Fig. 17. ANTICLINAL THEORY, GAS, OIL AND WATER

The application of this principle should be remembered when development work is being carried on in districts where folding obtains and where prospecting wells are being sunk to the deeper portions of known productive measures. In such cases, water sands containing traces of oil and gas may be encountered at the depth at which oil was to be expected and the futility of further prospecting in the immediate neighborhood becomes thereby demonstrated.

When strata have been disturbed and dislocated so that they are no longer completely continuous, they are said to be *faulted*. The plane of fracture, known as the fault plane, is rarely vertical but will incline, thus leaving one side above the other. Normal faults (Fig. 18a) are those in which the upper side, or hanging wall, has



(a) NORMAL FAULT (b) THRUST FAULT

Fig. 18.

fallen to a relatively lower position than the foot-wall; thrust faults (Fig. 18b) are those in which the reverse is the case and the hanging wall has been thrust forward and pushed upward against the sloping fault plane surface of the foot-wall; these are more common than the former. Folding seldom exists without the presence of faults, varying in size from fractures of a few inches

to displacements of thousands of feet. Their influence on the accumulation of petroleum is discovered in the field only with great difficulty in many localities, and seems to follow no set rule.

A popular misconception seems to be that faults are inimical to structure associated with the presence of oil and that where faults may be observed, the prospects of finding oil are remote. While it is quite true that where the country is much 'broken up,' that is to say, faulted to an extreme degree, the conditions are not favorable and the discovery of oil in a well drilled in such a locality may prove the presence of petroleum for only a small surrounding area, yet it must be remembered that folding and faulting are the results of the same kinds of earth movements, and the two are usually associated.

The fractures or open spaces formed at the summits of anticlinal folds by faulting have in many cases, no doubt, provided space for the accumulation of vast quantities of oil. In other cases they have disturbed the measures to such an extent that they have lost such petroleum as may at one time have been contained therein. Such irregularities also tend to increase greatly the mechanical difficulty of drilling. Several well known examples exist where definite fault planes have been the sources of immense production. In such cases, as in the Ventura field, the direction of the fault plane when once ascertained determines the situation of the wells, which extend across the country in a narrow straight line. A frequent cause of monoclinal structure is the faulting that occurs at the time folding is going on, because the strata lack the necessary flexibility to lend themselves to bending into the anticlinal form and become broken.

In the brief review that has been given of the development of structural forms, it should not be imagined that folds have the beautiful symmetry usually ascribed to them in sketches, or that they are always easily deciphered in the field. They usually have one side steeper than the other, the side having the greater dip being in the direction from which the pressure was applied that caused the folding. It will be seen (Fig. 19) that under such a condition a marked difference obtains as far as the petroleum development is concerned and that the gently sloping side will offer room for more wells at shallow depths than does the more steeply inclined flank of the anticline.

Folds may turn under and back again as shown in Fig. 20, in which case they are known as overturns; they may, and usually do bend, and when the forces that have brought about the deforma-

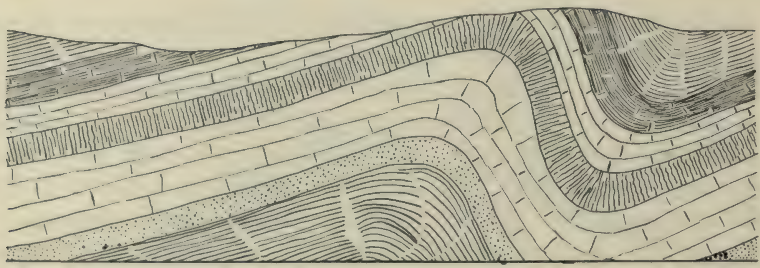


Fig. 19. ANTICLINE WITH ONE SIDE STEEPER THAN THE OTHER

Fig. 20. OVERTURN FOLD

tion of the strata have been applied from several different directions at different times the resulting structure and shapes may become exceedingly involved.

Frequently they will tend to flatten or broaden out in the direction of their strike. Or they may retain their folded structure but will dip as an entirety in the direction of the strike, in which case they are said to *plunge*. Either of the latter two examples may bring about the *dome structure* in which the measures dip away in all directions from some central point. Both from a theoretical standpoint, and from the results of actual developments of oil fields, the dome structure is seen to be the most favorable for the accumulation of bodies of petroleum. When the oil measures are overlain by an impervious stratum, namely, the cap rock, that prevents further upward migration of the oil and gas, the conditions are ideal for their gathering towards the summit of the measures, and this type is found in some of the most famous and productive districts. Perfect domes, however, are rare and they are more often found with one axis longer than the other, with the axes bent, and frequently with no

symmetry whatever as far as the relation of the dips to the axes is concerned.

It not infrequently happens in studying the geology of stratified rocks in the field that a form of structure similar to that indicated in Fig. 21 is found. This type, in which one series of strata is seen to

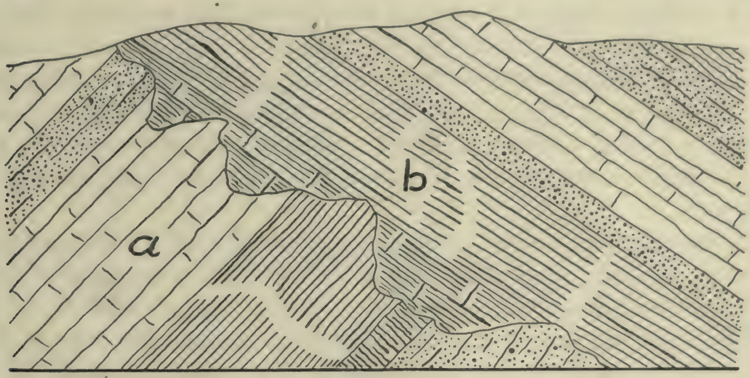


Fig. 21. UNCONFORMITY

lie unconformably on a lower series is known as an unconformity, and has its origin in conditions which were essentially that after the strata *a* had been deposited they were elevated, eroded, then submerged, and became the sea-bottom on which were deposited the strata *b*. Subsequently the entire mass has been elevated and tilted. It is evident that such forms indicate the elapse of long time intervals between the deposition of the two series and the determination of unconformities are important features in establishing the time relations of different strata. Sometimes the strata may be parallel (Fig. 22)

Fig. 22. UNCONFORMITY

and the only indication of the unconformity will be the uneven nature of the top of the older and lower series. More often, however, the dips take different directions.

The detection of the necessary evidence by which the structure may be learned is not always easily accomplished. The forces of erosion have been cutting and wearing away the surface, exposing outcrops at some points and obliterating the 'bed-rock' with detrital material at others, so that one learns to take advantage of every possible piece of evidence to be found. All dips are measured, faulting is closely studied and the distance of throw measured wherever possible, and all the data entered on as complete a topographic map as may be obtained.

Topographic maps show the relief or surface of the ground as it is today by means of contour lines, which are the lines drawn through all points having a common altitude. If one were to walk along the ground following the course indicated by a contour line on the map he would go neither up nor down but would remain constantly at the same elevation. Contour lines are arbitrarily spaced so as to represent equal successive vertical distances. Thus the 50-ft. contour along the coast would be the line made by the edge of the sea if it were to raise 50 ft.; the 100-ft. contour is 50 ft. above this, and so on. Many do not know the value of such maps, and the ease with which the topographic maps of the United States may be obtained for a small sum from the United States Geological Survey at Washington. An inquiry to the director thereof will bring an index map showing which portions of any state have been mapped and where these sheets may be purchased locally. In geological maps the underground position of oil-bearing measures is also shown by contour lines referred to sea level as a base, and designated with a minus sign prefixed when they signify depths *below* sea level, Fig. 23.

While it is of course unsafe to predicate the geological structure from map contours without field examination, yet these maps are a valuable help in the field and the topography frequently reflects the nature of the geology. Faults may be indicated by steep sharp scarps, and folding from hills and irregularities conforming in a general way to the underground structure, although as often as not the axis of an anticline will not be found at the summit of a hill but on one of the sides.

As a simple example of the determination of structure it will be seen (Fig. 24) that in going over the hill from north to south the dip at *a* would be found to be 21° N. and the measure noted as a brown shale; going further up the hill one passes over a body of

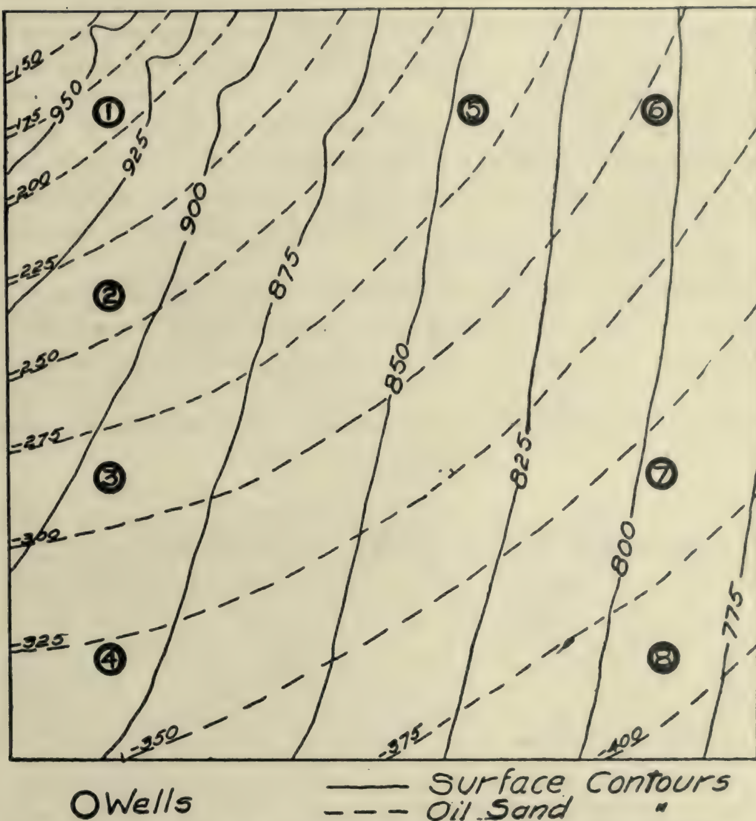


Fig. 23. TOPOGRAPHIC MAP SHOWING BOTH SURFACE AND UNDERGROUND CONTOURS

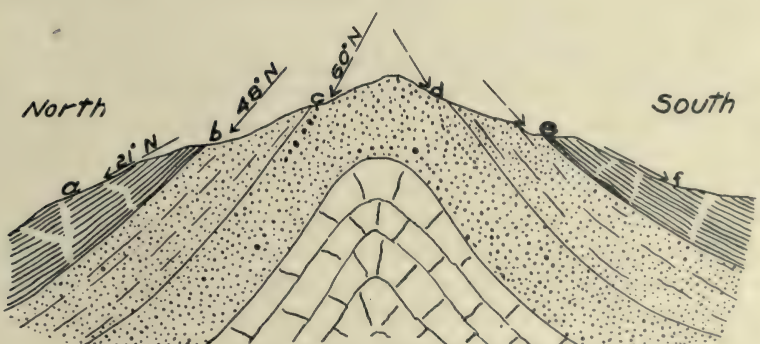


Fig. 24. DETERMINATION OF STRUCTURE BY OBSERVING DIPS

light sandstone with a steeper dip, say 48° N. at *b*, and beyond this at *c* a measure of brown sandstone with dips increasing from 60° N. up to 80° and more. When the crest of the hill has been passed the same measures are traversed again in reverse order and with approximately the same dips at *d, e* and *f*, except that now they point *south*. Such evidence indicates clearly that the structure is a simple fold and that as far as the section represented by the line of the walk is concerned, the fold is symmetrical.

Suppose, however, that faulting has taken place along the lines indicated in Fig. 25. Casual observation might ascribe a greater thickness to the measure than it really has and often it is only by the most painstaking care in differentiating between minor characteristics in exposures that one is able to detect such repetitions and

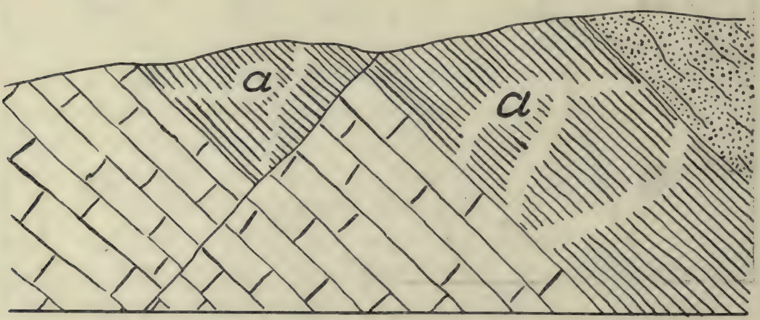


Fig. 25. ILLUSTRATING HOW THICKNESS OF STRATA MAY APPEAR GREATER, DUE TO FAULTING

establish the presence of faults. Or it may be that the structure is that shown in Fig. 20 and the dips all appear to have a single general direction. In this case the relative positions of the measures supply the key to the situation.

From the sketches shown of typical folds it is apparent that in nearly all cases where rolling hills represent anticlinal structure the dip of the strata is greater than the grade of the land surface, and that any single stratum approaches the surface as it rises, reaching the nearest point to the surface at the anticlinal axis. This rule obtains generally for monoclinal structure as well, and explains the well-known fact that holes sunk on the crest of hills are usually the shallowest, with the depths to the productive measure increasing in those further down on the slopes (Fig. 26). It should not be accepted as a rule that the anticlinal axis or summit conforms to the crest of a hill, as differential weathering and erosion may wear

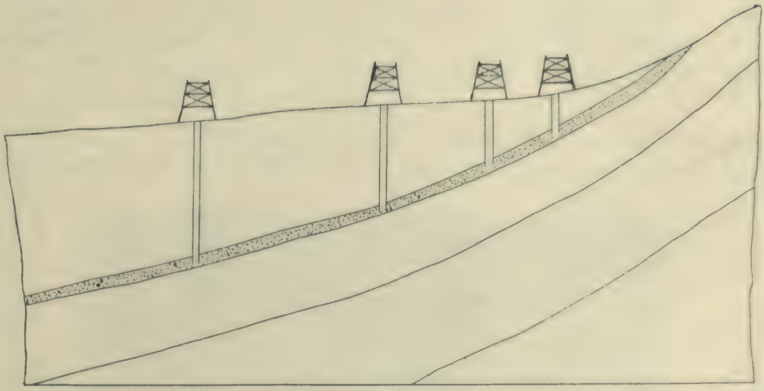


Fig. 26. SHOWING WHY THE SHALLOWEST WELLS ARE NEAREST THE CREST OF A HILL

away the softer strata under some conditions so that the highest point topographically lies off to one side and over one flank of the anticline (Fig. 27).

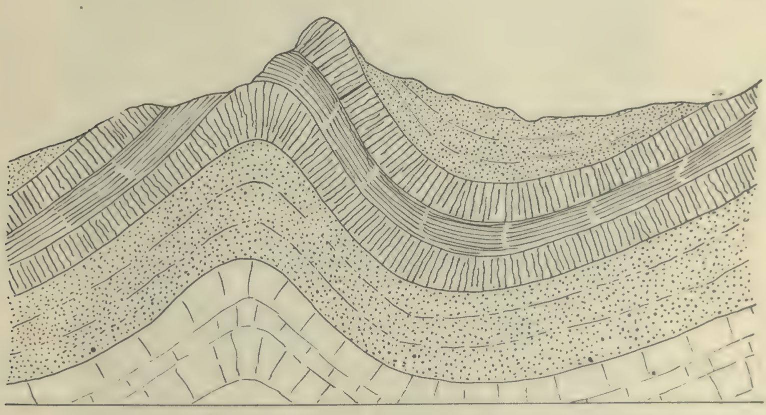


Fig. 27. DIAGRAM SHOWING THAT APEX OF FOLD IS NOT ALWAYS TOP OF HILL

The dip of a measure is of course not a constant factor, and as it falls away from the summit it tends to approach a horizontal position. When sufficient wells have been drilled along a line to establish the relation between the dip and the surface gradient, it is an easy matter to plat them to scale and to predict within narrow limits the depth of a well at any given point (Fig. 28). Such platting when carefully done helps to bring out the presence of minor folds or waves and irregularities in the measure, if such be present.

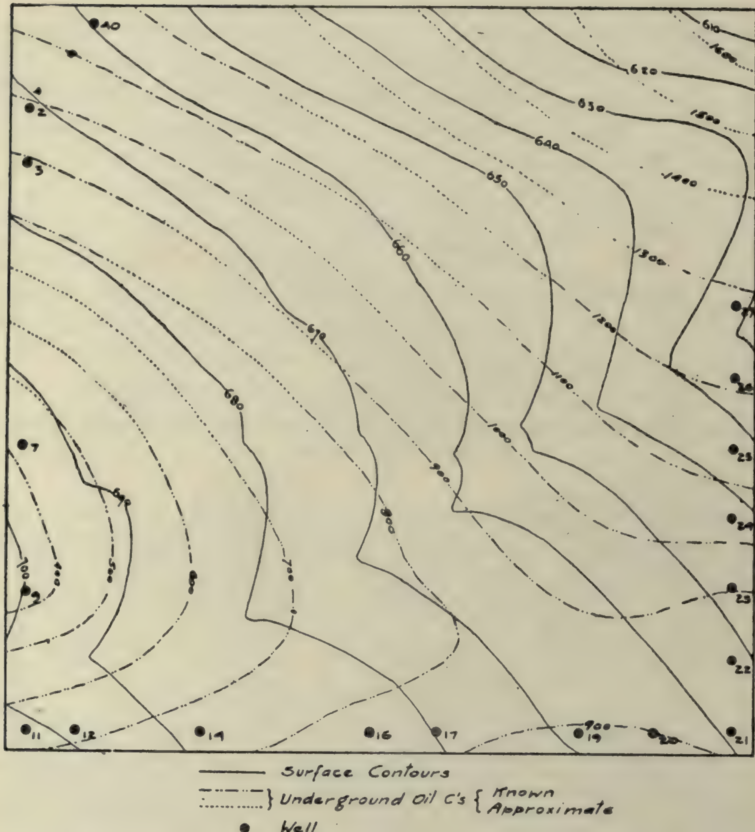


Fig. 28. SURFACE AND UNDERGROUND CONTOUR MAP FOR GRAPHIC REPRESENTATION OF OILFIELD STRUCTURE

Surface Indications of Oil.

Aside from the study of geological structure and the application of such information to the question as to whether or not oil may be found in underlying strata, there are certain occurrences of surface phenomena which often suggest the presence of oil and which, in fact, are what usually lead to the first hope or belief that oil may be present.

The first, and most commonly observed, of these are the seepages of oil found in districts all over the world. They are usually detected by the light iridescent film or play of colors on top of the water emerging from springs in ravines. Although the actual amount of oil present is apt to be very slight, occasionally it is present in greater quantities, but in any case the characteristic

odor of petroleum readily identifies it and distinguishes it from some of the compounds of iron that also form the colors on water and are often mistaken for oil indications. It may also be discriminated by breaking the film.

Seepages may result from fracture planes in the earth supplying a passage way for the oil from the point of origin to the surface, or

Fig. 29. OIL SEEPAGE NEAR KATALLA, ALASKA

by direct mixing at or near the surface of water with the oil from measures outcropping nearby. The nature of the oil may frequently be learned by observing it carefully. Asphalt oil tends to dry and form small deposits of solid asphalt, while that with a paraffin base will flow for a longer period, eventually forming small particles of a brown substance that often takes a reddish tinge.

In other occurrences the oil in its upward migration has been subjected to filtering processes which have removed from it the greater portion of its heavier constituents, leaving it light and clear, and it is evident that samples of such will be misleading if accepted as indications of the quality of petroleum that will be encountered with drilling. In any case, when oils have reached the surface the more volatile varieties will tend to disseminate more readily while the heavier ones will thicken and gather locally. Often a seepage of gas will lead to the discovery of petroleum when no signs of the oil itself may be found.

Other indications of the presence of oil, commonly observed, are the outcrops of oil-bearing strata. These may be detected by their appearance and discoloration, their odor, and by the test of placing a few grains in a test-tube containing chloroform and watching for the brown color that will appear if these hydro-carbons are present. Slight showings of sulphur flakes may be found in them also, and their effect on vegetation is often so pronounced in contrast with that supported by the neighboring non-petroliferous measures, that, at some seasons of the year, such an outcrop may be traced across the country for considerable distances by observing only the marked difference in the appearance of the grass or other growths. All these indications, however, are much more apparent with outcrops bearing an asphalt oil than when the oil is the lighter and more volatile variety with a paraffin base. In the latter case, the faint odor of vaseline may be the only means of its identification. Outcrops of measures heavily impregnated with asphalt oil make excellent road-building material and are frequently quarried for this purpose.

A third form of indication occurs when neither oil nor gas may be definitely found but when the evidence of their action on other materials may be observed, as in the case of the presence of small flakes of sulphur and the foul-smelling gas hydrogen sulphide, associated with the fields where limestone is the source of the oil. In these districts the outcrops of the oil-bearing strata rarely carry direct indications, but the sulphur deposited along small stream courses and the hydrogen sulphide, detected particularly in damp weather, are suggestive guides.

It must not be thought, however, that every petroleum seepage or outcrop of an oil sand is indicative of the presence of oil in abundant quantities. Many seepages are found but few develop into oil fields, because the oil may never have been present in the

strata except in minute quantities, or, if there at one time, it may have escaped because of any one of a number of geological changes and the resulting alterations in underground conditions and structure.

Location and Spacing of Wells.

From the foregoing it is evident that, as far as is possible, the geological conditions should determine the locations of wells, especially in a new field where the first test, or 'wildcat,' well is to be drilled without positive knowledge of the presence of oil. When the structure is found to be anticlinal or that of a dome, and topography, ownership, etc., permit, the well should be placed on the summit of the fold where the prospects are that the best showing will be obtained at the shallowest depth, thereby minimizing the expense. When the well is to be drilled to reach a measure that is exposed at the surface, its dips and surrounding strata should be learned. Faults, if any, should be determined, and, from the data thus obtained and the knowledge as to the approximate depth at which it is desired to penetrate the oil sand, a rough idea may be reached as to the distance from the outcrop the well should be placed.

Thus if the surface exposure dips 30° and it is believed from local evidence that the lessening in dip is such that the average dip to where the measure is 800 feet deep is 5° less, or 25°, then the determination of the horizontal distance to a point 800 ft. above the measure becomes a simple problem, in this case working out to be 1715 ft. If in this distance the elevation falls off, say 70 ft., below that of the outcrop, then the actual distance to be drilled becomes lessened to that extent. Such computations, due to the variable factor of the change in dip, are necessarily of indefinite value and can be used only in a very broad way. They do, however, bring out the point that where measures are steeply inclined it is to be expected that the field will be narrow and a prospect well should be situated nearer the outcrop than where the dip is known to be more gently sloping. Such freedom as outlined above does not of course hold true where property lines prescribe limits within which wells must be situated.

Since a well when once drilled derives its oil from a zone extending in all directions about it, the natural tendency is to place it as near to the neighbor's property as possible in order that a portion of his oil may be drawn on and contribute to the supply. For this reason mutual agreements are usually adopted by adjoin-

ing owners, to the effect that neither will drill within a certain distance of the line, say 100 or 150 feet. For this reason also the outside locations, that is, the locations along the line at this stated distance, known as the 'line wells,' are usually drilled first and the inside locations later.

The spacing of wells is a matter that must depend entirely on local conditions, particularly those relating to the nature of the sand or other productive measure, and the gravity of the oil. If the oil is heavy and viscous or the source is tight, they may be situated much more closely together than where the oil is light and flows readily and the containing measure is open and porous. It is seldom advantageous to distance them less than 100 ft., while 300 ft. is more often good practice, and even 500 ft. or greater where gas pressures are high and the oil very mobile. The close crowding of wells that has resulted in some fields from the land being owned or leased in small parcels has meant a distinct economic waste where half the number would have sufficed to produce an equivalent amount of oil.

When the outside wells have been finished, the inside locations are then drilled, usually according to some definite plan or system worked out by which it is designed to secure all the recoverable oil with a minimum number of wells and without interfering with surface improvements such as tanks, buildings, or sumps.

Logs.

The log is a record of the well from the time of its beginning until its completion and shows the depths and thicknesses of strata drilled, points at which water, gas, and oil are found as well as other data relative to its history. To this end the log should also contain not only the record of casing inserted but also any other features that may be of importance at some later time, such as unusual fishing jobs, tools, or casing left in the hole and sidetracked. Such items, while apparently of little moment at the time as far as the log is concerned, may have an important bearing on work being carried on with the well possibly several years later when the knowledge as to just where different troubles had happened in the first drilling may prove of considerable value.

The nomenclature of the oil fields has many unique names and strange uses for old words. Drillers from different parts of the country meeting on the same ground find themselves using different expressions for the same thing, as the Texan's use of 'gumbo'

for the Pennsylvanian's 'sticky clay,' and the latter's 'shell' for the Texan's 'rock,' both meaning any hard substance. Such localisms have resulted in there being no common tongue in the description of material drilled, and the knowledge of what these expressions may mean is rather necessary to a complete interpretation of the usual log.

Logs may be compiled from daily drilling reports where they are in use. Where they are not, the log is usually kept in a notebook by the drillers or the foreman. The use of drilling reports, however, is far more satisfactory, especially if supplemented by a diary kept by the superintendent. The usual shift in oil field work is twelve hours, from noon till midnight, and from midnight till noon; two reports, one for each crew, show the advance made during the day and such other information as is desired. These blanks are printed in triplicate and bound into books of 50 or 100 sets; two copies are torn from the book and turned in at the end of the 'tower,' the oil field term for shift. One copy goes to the main office, the other remains at field headquarters, the third stays with the book at the well.

Drilling Report.

Well No. .... Date....................

Came on tower at........................ { Midnight / Noon

Began tower at ....ft.
During tower made ....ft.
Depth at end of tower ....ft.

Formation.

From .... to .... ft. ....
From .... to .... ft. ....
From .... to .... ft. ....
Struck water at ....
Struck gas at ....
Struck oil at ....
Size of casing ....
Casing in hole at beginning.........................
Casing put in during tower..........................
Casing now in hole...................................
Remarks ....
....
....

Driller ....

Tool Dresser ....

Note all changes in formation, examine all machinery and tools carefully before using and report all accidents promptly to office.

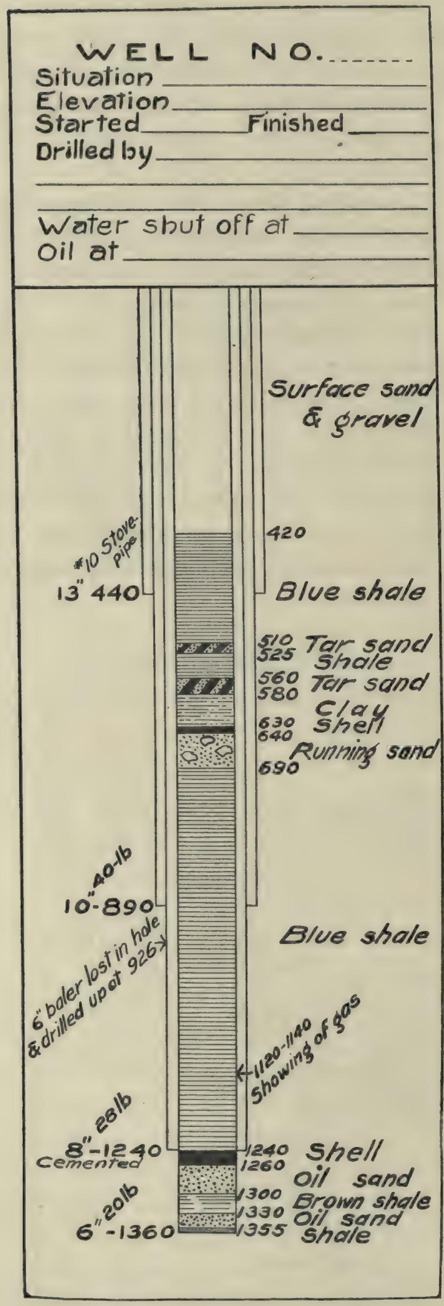


Fig. 30. GRAPHIC LOG

When wells have been completed, the best manner of compiling the logs for future reference is some form of graphic representation. This may be an elaborately colored drawing, or a more simple sketch, prepared on tracing cloth so that blue prints may be taken from it, along the lines of the typical log shown in Fig. 30, which embodies all the information necessary for ordinary reference.

When several wells have been drilled in a neighborhood, the use of models, very similar to those prepared at mines to show the positions of orebodies, will bring out the features of the underground geology, particularly the dip and strike of oil sands. One may easily be made by letting a horizontal board represent any

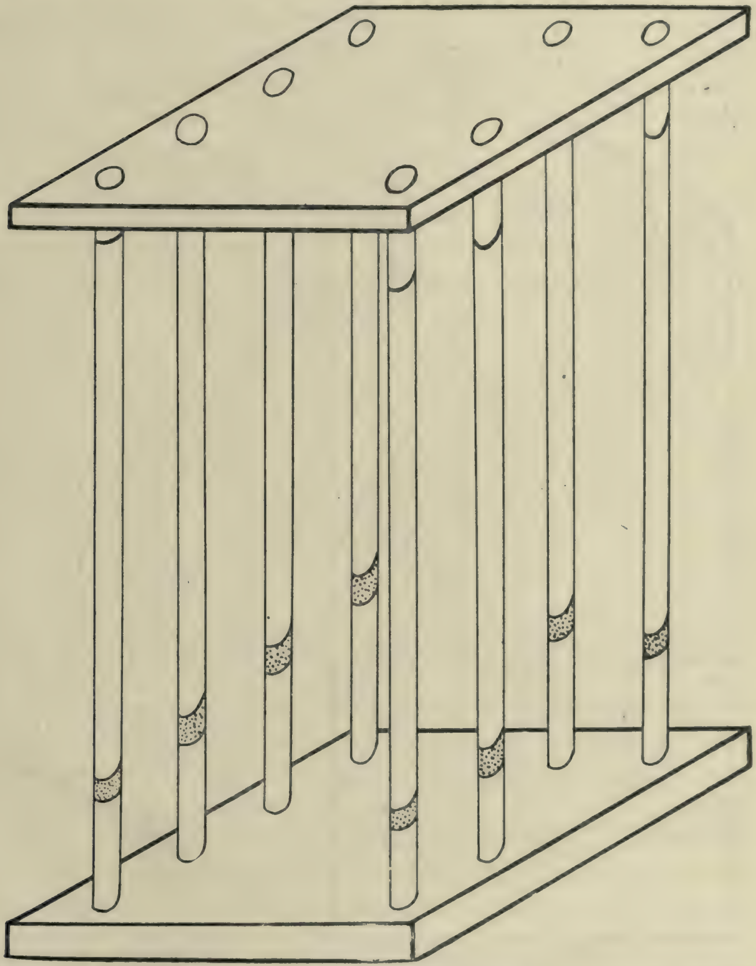


Fig. 31. DIAGRAMMATIC REPRESENTATION OF A GROUP OF WELLS SHOWING POSITION OF OIL-SAND

datum plane higher than the highest point on the property; the positions of the wells are then platted to scale on the board, holes drilled through it at these points and long round wooden pegs, representing the wells, slipped into the holes (Fig. 31). On the pegs are painted in various colors the data to be shown, such as elevation of land surface at well, depths of water sands, tar and oil sands, etc., at a scale of either one or two inches to the hundred feet. The same may be shown pictorially, if desired, in a stereographic projection similar to that in Fig. 32, which is a record of the same data shown in the model in Fig. 31; this latter method is one followed by many of the larger companies.

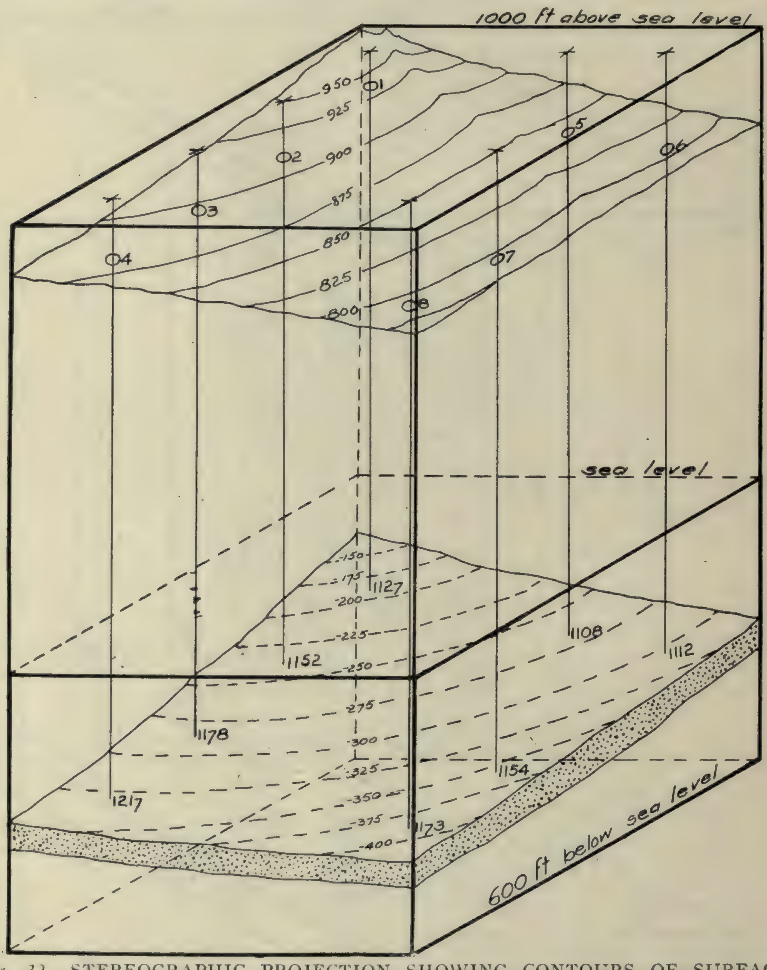


Fig. 32. STEREOGRAPHIC PROJECTION SHOWING CONTOURS OF SURFACE AND OIL-BEARING STRATUM

CHAPTER III.

RIGS AND EQUIPMENT.

The marvelous growth of the petroleum industry in a few years has brought out all the ingenuity of the men connected with it to meet the drilling conditions encountered in the different fields. This rapid development and the curious nature of the work, in which conditions are unlike almost any other branch of engineering, have resulted in wide divergences of opinion as to the best methods to follow, and it is not uncommon to see quite different outfits and methods in the same field and working under similar drilling conditions. Each will have its votaries and each will get the hole down, but the natural hazard of the work is such a factor, and so often the unforseen happens, that unless the merits of one method are sweepingly greater than the other it is often impossible to choose between them. The normal duty of materials used in drilling is not unduly severe; the trouble arises with the occasional incidents that are bound to occur and which suddenly throw a great strain on some one part of the equipment. An example of this is seen when a bailer sticks in the hole, through the crumbling material in the sides falling in about and over the bailer so that it is held tight. The wire line that sustains the bailer ordinarily may never have to hold up a weight greater than a ton, yet in the pull that comes with trying to free the bailer it may be required to withstand a strain of many tons before it is either loosened or the line broken.

The application of engineering data to the problems of drilling, except in a cut-and-slash way, is almost impossible as far as satisfactory results are concerned. One man may build a certain type of derrick and find it well suited to his work; his neighbor may build one exactly like it, and be drilling in the same kind of ground, but 'freezes' the casing through caving material falling in and binding the pipe. When he tries to pull the pipe up he pulls in the derrick instead. The same difficulty was just as liable to happen with the first operator, and illustrates the constant danger of mishaps in drilling wells. It also accounts, with the increasing depths and heavier tools used, for the increase in weight of almost everything

in the way of equipment connected with drilling, and nowhere is this more apparent than in the rigs themselves. The term 'rig' is meant ordinarily to apply to the derrick, timbers and wheels, and does not include the boiler, engine, and other equipment.

Standard Drilling Rig. Except in rotary wells, which use the bare derrick only, the rig has two principal parts; first, the derrick itself directly over the well; and second, the belt-house, which is the long, narrow building serving as a housing for the belt and band wheel and connecting the derrick with the engine house, covering the engine or motor. These rest on suitable foundations

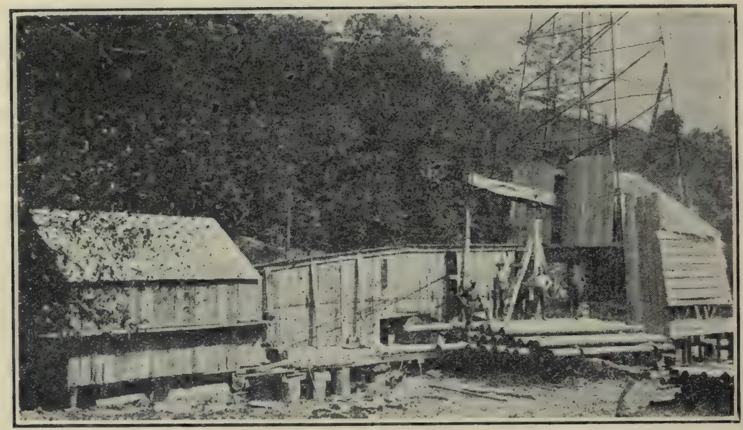


Fig. 33. STEEL DERRICK

of heavy timber which, with the heavier posts and walking beam, are known as the 'rig timbers.'

With the exception of a comparatively small number of steel structures, derricks are built of timber. The former have not proved unsatisfactory, but their cost has been against them, as well as the difficulty in securing men understanding their erection. The itinerant rig-builder is found in all the fields and usually builds the rig by contract instead of day wages.

Where hard woods, such as oak or chestnut are found, they make excellent derricks, but more often some of the many forms of pine or other soft wood are the only available timber and the difference in their relative strengths govern somewhat the dimensions of the lumber in any particular rig.

The derrick is supported on posts which rest in turn on a suitable foundation of either timber or concrete, known as the 'derrick

footing.' Light rigs need no concrete and often but little timber for the footing, while heavy ones may use a considerable quantity, as is seen by reference to the rig list on page 61, which provides for 1410 board feet of redwood for each of the four corners. This corner, in which the redwood boards are 3 in. thick, has a base of two layers 10 ft. square with succeeding pyramidal layers 9 ft. square, then 8, 7, 6 and 5 feet, the layers alternating in the direction of lay of the boards. Such a corner is very good for heavy work, as it is firm and yet has the slight 'give' to it that is desired. It is, however, very expensive and for this reason should be dispensed with where lighter and more simple timbers, or concrete, will serve as well. The latter is being used more and more and may be easily made of a 1:3:6 mix, 5 ft. high with a 5-ft. base and 3-ft. top. Loose surface material should be removed and the bottom of the forms placed below the surface so that the top of the concrete is a foot or two above it. Above the corners are placed the side sills (17), and the derrick sills (18), the latter supporting the floor of the derrick. (These numbers and similar ones following refer to Fig. 34 on page 58.)

The other principal foundation timbers are the mud sills (28), the main sill (27), the pony sill (36), the sub sill (45), the nose sill (46), engine sills (51), and engine block (41).

The derrick itself consists of four uprights (8), known as 'legs,' braced by horizontal girts (10) and diagonally-placed braces (11). Its size is designated by the size of the floor and the height, a 20 by 74 derrick having a floor 20 ft. square and being 74 ft. high, and this size has been used probably more than any other. It is rarely that the floor is made less than 20 ft. square, and the heavier types are 22 and 24-ft.; while the heights in recent practice are going more towards 84 ft. for wells using standard tools and 106, 114, and even 124 ft. with those using the rotary method.

The legs are built up by placing 2 by 10 and 2 by 12 planks trough-shaped, with each side taking the direction of one side of the derrick. Ordinarily one set of these, with an extra set for the first 18 ft., give enough strength; heavier derricks are supplied with two sets known as doublers, the entire length with a third set at the lower 18 feet. Besides the usual braces shown in Fig. 34, derricks requiring additional strength are 'sway-braced' by adding another set of girts on the outside of the legs opposite every other set of inside girts, and placing long braces between the outside girts (49)

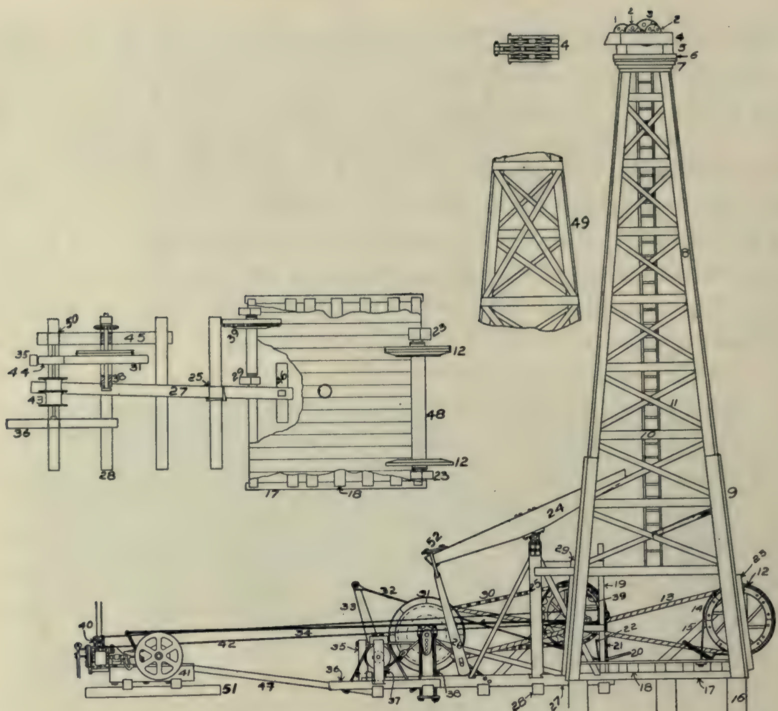


Fig. 34. PLAN AND ELEVATION OF STANDARD DRILLING RIG

SCHEDULE OF PARTS, STANDARD DRILLING RIG

1.—Sand line pulley. 2.—Casing pulley. 3.—Crown pulley. 4.—Crown block. 5.—Bumpers. 6.—Water table. 7.—Crown. 8.—Derrick legs. 9.—Doubler. 10.—Girt. 11.—Brace. 12.—Bull wheels. 13.—Bull rope. 14.—Bull wheel brake band. 15.—Bull wheel post brace. 16.—Derrick foundation post. 17.—Side sills. 18.—Derrick sills. 19.—Headache post. 20.—Calf wheel brake lever. 21.—Calf wheel brake band. 22.—Sand reel lever. 23.—Bull wheel post. 24.—Walking beam. 25.—Sampson post. 26.—Pitman. 27.—Main sill. 28.—Mud sills. 29.—Calf wheel post. 30.—Calf wheel sprocket chain. 31.—Band wheel. 32.—Sand reel reach. 33.—Sand reel swing lever. 34.—Reverse lever rod. 35.—Back brake. 36.—Tail sill or pony sill. 37.—Sand reel post. 38.—Jack post. 39.—Calf wheel. 40.—Throttle valve and wheel. 41.—Engine block. 42.—Telegraph cord. 43.—Sand reel. 44.—Sand reel friction pulley. 45.—Sub sill. 46.—Nose sill. 47.—Engine block brace or bunting pole. 48.—Bull wheel shaft. 49.—Sway brace. 50.—Knuckle post. 51.—Engine block mud sills. 52.—Tail board.

The construction of the rig starts with placing the mud-sills (28) and the main-sill (27) (Fig. 35), and the derrick foundations are then set so that the derrick floor is even with these, except when a rotary derrick is being fitted for standard tool work, when of course the mud-sill and main-sill are placed to conform with the position of the derrick as it was erected for the rotary work. The derrick is next run up, heavily nailed and surmounted with the crown (7), the water table (6), the bumpers (5) and the crown block (4), and the latter faced with hard wood bearings for the sheave-wheels on which run the various ropes.

Next are put up the jack-post (38), the bull-wheel posts (23), the bull-wheels (12), the calf-wheel (39), and engine foundation (41). The sampson-post (25), walking-beam (24) and band-wheel (31) are not erected until the bull-wheels may be used for pulling them into place. Finally the sand reel (43) and friction pulley (44) are built in, having been left till the last because they must be placed so that the friction pulley runs true with the band wheel. Rough 1 by 12 lumber is used for the engine and belt houses and for the lower portion of the derrick if it also is to be housed. Corrugated iron for this purpose is a trifle more expensive, but the lessened construction cost, the diminished danger of fire and the better protection of the belt make the added expense well worth

Fig. 35. MUD AND MAIN SILLS IN PLACE

while and it is finding an increased use. A plank-walk connects the engine house with the derrick and a casing rack, of 6 by 6 or 8 by 8 timbers, is built beside the walk for the purpose of holding casing, tubing and such equipment as cement tanks at the time the well is being cemented.

The well is not drilled exactly in the centre of the square floor-space, but is started either 8 or 9 ft. from the front side, towards the engine house, leaving either 11 or 12 ft. between it and the opposite side in a 20-ft. floor.

Derrick Lumber List.

The following lumber lists are typical of the lumber required for derricks using the different methods and for drilling shallow or deep wells. The details of construction vary

greatly in minor particulars but those cited here are in common use and well suited to the class of drilling for which they are designed.

The wheels for use when the cable-tool method is being followed are about the same size in all the styles of derricks. The material for a 10-ft. band-wheel is as follows:

24-2/12 x 16 Soft pine (preferably surfaced)
64-1/ 8 x 10 ft. circle cants
24-1/ 8 x 7 ft. circle cants
8-3/ 8 x 7 ft. circle cants
16-3/ 8 x 7 ft. circle grooved cants (8 only for single Tug)

Material for bull wheels (double tug):	Material for calf wheel:
80-1/8 x 8 ft. circle cants	40-1/ 8 x 7′ 6″ circle cants
8-3/8 x 8 ft. circle cants	8-3/ 8 x 7′ 6″ circle cants
16-3/8 x 8 ft. circle grooved cants	2-2/12 x 16″ pine
32-1½ x 9 hard wood pins	2-3/ 8 x 16 pine
4-2/12 x 18 pine	

Lumber List for Light 20 x 74-ft. Derrick for Cable Tools.

1-12 x 12 x 12 x 26	1-6/ 6 x 24	36-2/10 x 16
1-22/24 x 9	5-6/ 6 x 18	3-2/ 8 x 20
1-14/14 x 30	2-6/ 6 x 14	22-2/ 8 x 16
1-14/14 x 20	2-6/ 6 x 16	12-2/ 6 x 20
1-16/16 x 14	2-5/16 x 16	12-2/ 6 x 18
1-16/16 x 16	1-6/14 x 12	4-2/ 6 x 26
8-14/14 x 16	1-5/14 x 12	5-2/ 6 x 12
1-12/12 x 16	3-4/ 6 x 14	5-2/ 4 x 20
1-12/12 x 20	48-2/12 x 20	9-2/ 3 x 16
1-10/12 x 26	12-2/12 x 18	56-1/ 6 x 16
2- 8/ 8 x 22	8-2/10 x 26	85-1/12 x 16
1- 8/ 8 x 20	7-2/10 x 24	30-1/12 x 18
8- 6/ 6 x 20	9-2/10 x 18	95-1/12 x 20
1- 6 x 6 x 6 x 16-9	1-6 x 6 x 6 x 16-16	60-1/12 x 14

Lumber List for Medium Weight 20x84-ft. Derrick for Cable Tools.

1-16/16 x 30	3-6/ 6 x 16	6- 2/ 6 x 28
1-16/16 x 16	1-6/18 x 18	45- 2/12 x 20
1-22/22 x 9	1-6/18 x 14	30- 2/ 4 x 16
2-16/16 x 18	1-5/16 x 14	10- 1/ 3 x 16
6-16/16 x 16	1-6/ 6/6/16 x 9	80- 1/ 6 x 18
2-16/16 x 18	1-6/ 6/6/16 x 14	30- 1/ 6 x 16
2-14/14 x 20	8-4/ 6 x 18	30- 1/ 6 x 14
1-16/16 x 20	8-2/12 x 36	125- 1/12 x 20
2-12/14 x 24	4-2/12 x 32	115- 1/12 x 18
1-12/12 x 20	8-2/12 x 28	70- 1/12 x 16
4-10/12 x 20	12-2/12 x 24	36- 1/12 x 14
10- 8/ 8 x 20	20-2/12 x 16	1-16/16 x 14 Oak
40- 3/12 x 20	20-2/10 x 16	1-16/16 x 6 Oak
1-14/30 x 26	6-2/10 x 20	1- 3/12 x 6 Oak
2- 3/18 x 18	12-2/ 8 x 20	2- 6/ 6 x 14 Oak
2- 3/ 8 x 14	12-2/ 6 x 20	1-14/14/14/30 x 26
1- 6/ 6 x 30	12-2/ 6 x 18	
2- 6/ 8 x 18	12-2/ 6 x 16	

Lumber List for Heavy 20 x 84-ft. Derrick for Cable Tools.*

6-16/16 x 18	1-6/ 8 x 16	2-3/16 x 20
1-16/16 x 16	1-6/ 8 x 12	12-1/ 3 x 14
2-16/16 x 16	2-6/ 8 x 16	2-6/ 8 x 18
1-16/16 x 20	1-6/ 6 x 20	1-5/16 x 14
1-16/16 x 32	2-4/ 6 x 20	2-2/ 4 x 16
3-14/14 x 14	6-4/ 6 x 16	2-2/ 4 x 18
1-24/24 x 10	50-2/12 x 20	10-2/ 4 x 20
1-14/14/30 x 26	8-2/12 x 18	2-5/16 x 14
1-12/12 x 26	8-2/12 x 16	16-2/ 6 x 14
1-12/12 x 22	6-2/10 x 26	12-2/ 4 x 16
3-14/14 x 14	6-2/10 x 18	65-1/ 6 x 16
1-12/12 x 16	50-2/10 x 16	10-1/ 6 x 20
3-12/12 x 24	8-2/ 8 x 16	65-1/12 x 16
2-12/12 x 30	1-6/6/6/16 x 12 Oak	30-1/12 x 14
2-10/12 x 22	1-3/12 x 6 Oak	40-1/12 x 18
13-10/10 x 20	2-2/ 6 x 28	60-1/12 x 20
1- 6/ 6 x 18	2-2/ 6 x 26	34-2/12 x 24
40- 3/12 x 20 Redwood	2-2/ 6 x 22	16-2/12 x 34
36- 3/12 x 24 Redwood	10-2/ 8 x 20	2-6/ 6 x 14 Oak
12- 3/12 x 18 Redwood	10-2/ 6 x 18	
1- 6/ 8 x 30	10-2/ 6 x 16	

Lumber List for 24 x 106-ft. Derrick for Rotary Drilling.

1-22/24 x 9	84-2/12 x 24	8-2/ 8 x 16
2-14/14 x 16	20-2/12 x 22	8-2/ 6 x 22
2-14/14 x 24	40-2/12 x 20	8-2/ 6 x 20
2-12/12 x 20	24-2/12 x 18	8-2/ 6 x 18
2-10/10 x 26	58-2/12 x 16	16-2/ 6 x 16
8-10/10 x 24	6-2/10 x 18	20-2/ 6 x 24
10- 8/ 8 x 20	4-2/10 x 20	30-2/ 6 x 14
1- 8/ 8 x 24	56-2/10 x 16	60-1/ 6 x 16
4- 6/ 6 x 20	8-2/ 8 x 28	225-1/12 x 16
2- 6/16 x 14	26-2/ 8 x 24	125-1/12 x 20
2- 6/ 6 x 12 Oak	10-2/ 8 x 22	24-2/ 4 x 16
1- 4/ 6 x 20	8-2/ 8 x 20	
6- 4/ 4 x 14	8-2/ 8 x 18	

Lumber List for 24 x 106-ft. Combination Rig, Medium Weight, for Both Rotary and Cable Tool Drilling.

1-16/16 x 30	5- 4/ 6 x 16	16-2/ 8 x 24
2-16/16 x 20	2- 6/16 x 14	8-2/ 8 x 22
6-16/16 x 16	1- 5/16 x 12	8-2/ 8 x 20
2-14/14 x 16	1- 6/16 x 12	8-2/ 8 x 18
3-14/14 x 12	1-16/16 x 14 Oak	10-2/ 8 x 16
2-14/14 x 24	1-16/16 x 6 Oak	18-2/ 8 x 20
1-14/14/14/30 x 26	2- 6/ 6 x 12 Oak	8-2/ 8 x 18
1-12/12 x 26	1- 3/12 x 6 Oak	16-2/ 8 x 16
1-12/12 x 24	60- 2/12 x 24	6-2/ 4 x 26
1-12/12 x 22	10- 2/12 x 22	20-2/ 4 x 16
1-12/12 x 20	50- 2/12 x 20	60-1/ 6 x 16
2-10/10 x 26	30- 2/12 x 18	150-1/12 x 20
8-10/10 x 24	66- 2-12 x 16	30-1/12 x 18
10- 6/ 6 x 16	6- 2/10 x 18	30-1/12 x 24
4- 8/ 8 x 20	4- 2/10 x 20	15-2/12 x 20
1- 6/ 6 x 20	56- 2/10 x 16	6-3/12 x 20
1- 6/ 6 x 26	8- 2/ 8 x 28	

*This may be used as a 'combination rig,' for both rotary and cable-tool drilling by the addition of another set of engine-sills and block.

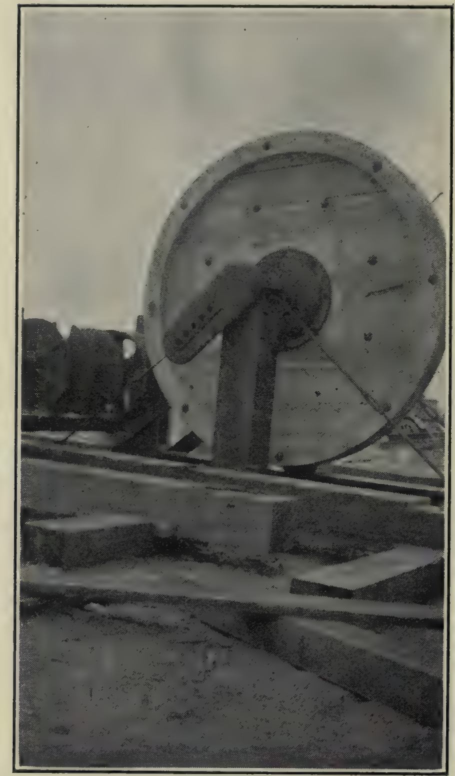


Fig. 36. BAND-WHEEL

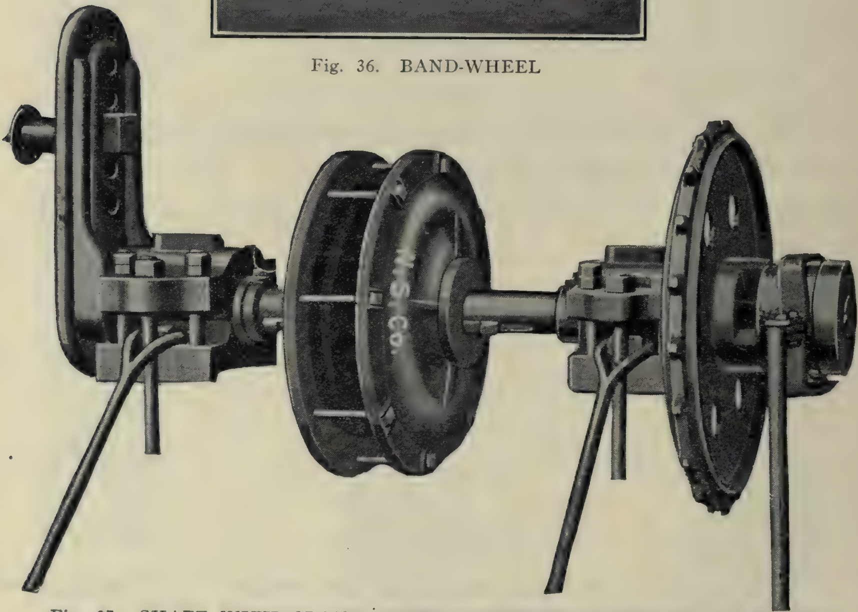


Fig. 37. SHAFT WITH CRANK, BOXES, FLANGES, SPROCKET AND CLUTCH

Motive power passes by belt from the engine-pulley to the band-wheel, and from the band-wheel it is transmitted to the various moving parts. This wheel is 10 ft. diameter, built of lumber and runs on a crank-shaft, supported by boxes on the jack-posts. Figure 37 illustrates the crank-shaft carrying, from left to right, the crank used for actuating the walking-beam, a jack-post box, the band-wheel flanges, the second jack-post box, the clutch-sprocket and clutch. The sprocket carries the chain which drives the calf-

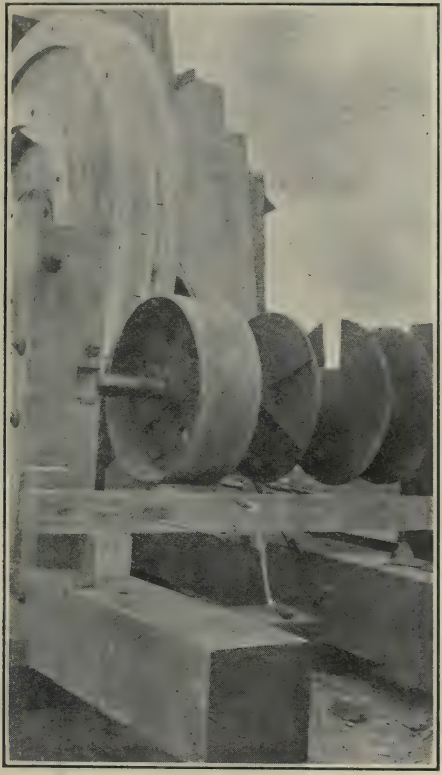


Fig. 38. SAND-REEL

wheel and is not fastened to the shaft but turns only when the clutch, which is keyed to the shaft, has been thrown over so that it meshes with an opening in the sprocket. On the clutch side of the band-wheel, there is built either one or two 6½ or 7 ft. grooved wood tug-pulley circles, on which run the bull-ropes that drive the bull-wheels.

The sand-reel is a drum on which is wound the sand-line that carries the sand-pump, or bailer, in and out of the hole. It is

turned by means of a friction pulley (44) pressed against the band-wheel by pulling the reach-rod (32) and the swing-lever (33); its speed is retarded by swinging the friction-pulley back and forcing it to bear against the back-brake (35). The reels are made with either single or double drums. For deep-hole work the latter are now almost universally used, one drum serving to hold that portion of the line not being used. It passes from the sand-

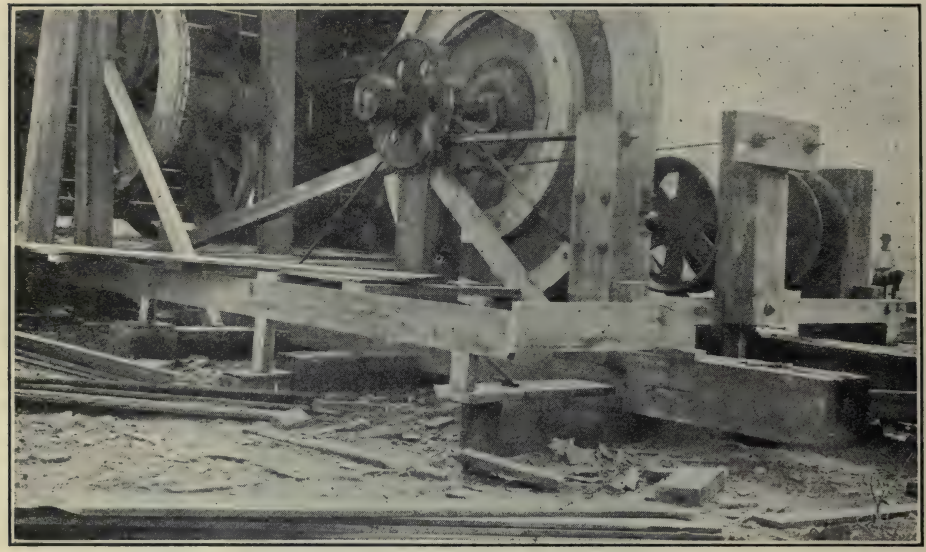


Fig. 39. RELATIVE POSITION OF CALF-WHEEL, BAND-WHEEL AND SAND-REEL

reel up on the outside of the derrick, over the sand-line sheave (1) and down inside the derrick.

The bull-wheels (Fig. 40) are built on a 16-in. bull-wheel shaft (48) supported at each end by the bull-wheel posts (23). The line carrying the tools used for drilling is wound on this shaft and passes up inside the derrick and over the crown-pulley (3). The wheels are of wood, 8 ft. diameter, and the one in line with the grooved circle on the band-wheel (Fig. 36) is similarly grooved in order to carry the bull-rope for power transmission. This wheel is known as the bull-wheel tug-pulley and has two such circles when two bull-ropes are used. The rim of the wheel at the other end of the shaft is surrounded with an iron brake-band, to retard the speed of the tools when being lowered into the hole and at other times to prevent the wheels from moving.

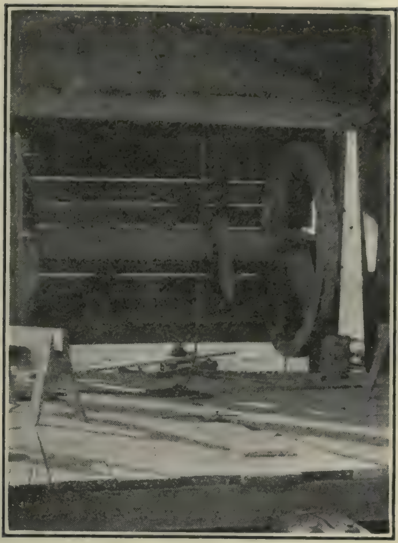


Fig. 40. BULL WHEELS

The calf-wheel (Fig. 41) is a comparatively recent innovation for handling casing without having to disengage the drilling-line from the tools for that purpose. It has a single wheel, placed at one end of a shaft that is supported by two posts (29), and, like the

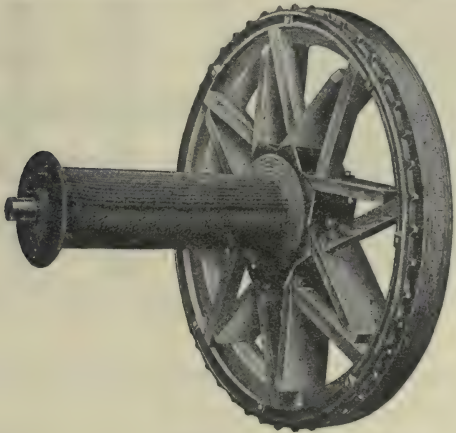


Fig. 41. CALF WHEEL

bull-wheel, is controlled by a brake-band. When first used it was driven from the band-wheel by ropes, as is still done with the bull-wheels, but this has now been almost entirely discarded in favor of the more positive chain drive, the chain running from the clutch

sprocket on the band-wheel shaft to an iron sprocket rim attached to the calf-wheel (Fig. 42). The calf-line passes from the calf-wheel shaft over one of the casing-pulleys (2), and thence back and forth between these and a snatch-block. Ordinarily there are seven lines between the latter and the casing-pulleys, but when the weight to be sustained in taking heavy pulls on casing demands nine lines instead of seven, a fifth casing-pulley is inserted between

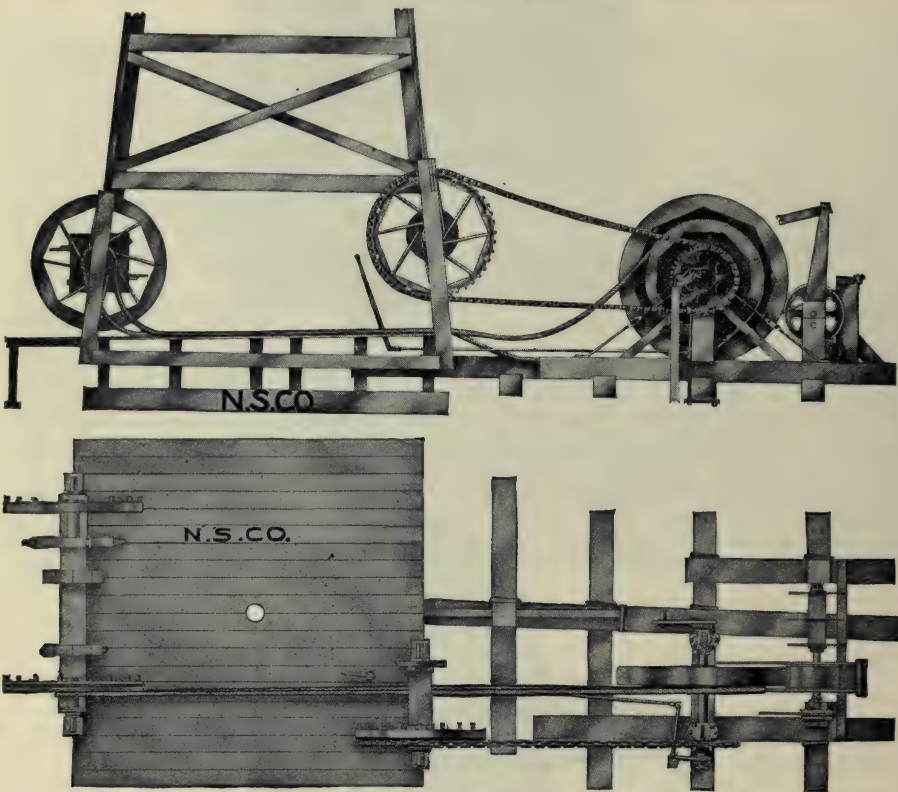


Fig. 42. ELEVATION AND PLAN OF IDEAL RIG IRONS WITH CLUTCH SPROCKET ATTACHMENT

the usual crown-block and an additional parallel piece of timber placed on the bumpers.

The crank shown at the left end of the main shaft in Fig. 37 turns with the band-wheel and by its off-set imparts the up-and-down motion to the walking-beam by means of a wrist-pin passed through one of the holes and the opening in the pitman (26). The length of the movement or sweep of the beam depends upon which of these holes is used, within limits of about 2 to 5 feet. The one

nearest the shaft is known as the first hole, the next succeeding as the second hole, and so on. The first hole is rarely used in drilling but is the principal one employed in pumping.

All the metal parts used in the construction of a derrick with the exception of the nails, bolts, sand-reel and guy wire, are known collectively as the 'rig irons,' and designated by the size of the crank-shaft that carries the band-wheel. Rig irons of the 4-in. and 5-in. sizes are used only for fairly light work and the 6-in. commonly employed for heavier duty. Recently 7½-in. irons have been tried with marked success where the conditions are such as to require unusually heavy tools and equipment.

Rig Iron List.

1, 7½-ft. Shaft with crank, wrist pin, set of 36-in. band wheel flanges and bolts, collars and keys, and clutch sprocket.
1, Sprocket tug-rim for calf-wheel.
1, Jack-post box and cap.
1, Calf-wheel box and cap.
4, Turnbuckle rods.
2, Jack-post rods.
1, Jack-post plate.
4, Eye-bolts.
4, Double-end bolts.
1, Set center irons and bolts, for walking-beam.
1, Set bull-wheel gudgeon, and brake-band.
1, Set calf-wheel gudgeons.
1, Brake-band for calf-wheel.
1, Walking-beam stirrup.
1, Crown pulley.
1, Sand-line sheave.
4, Casing-line pulleys.
55, feet of sprocket chain, for calf-wheel drive.

With the increase in the size and weight of equipment has come the introduction of iron and steel for many parts formerly made exclusively of wood. The wood pitman, bull-wheel shaft, calf-wheel, and crown-block may all be replaced with metal forms of greater strength and durability. Usually when the severe duty of drilling a well is over, and it has been put to pumping, the metal parts are replaced with the cheaper wood construction and moved to a new drilling-well.

Engines and Boilers. The well-drilling engine is a remarkably efficient piece of machinery when its low cost, the service required of it and the treatment it receives are taken into account. The

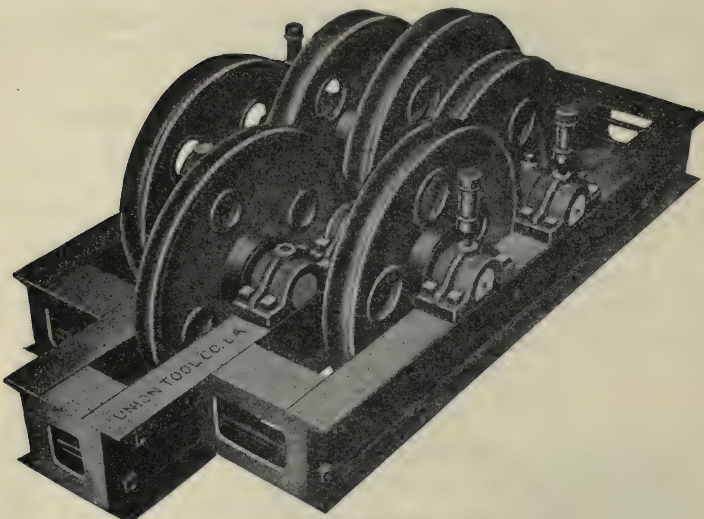


Fig. 43. IRON CROWN BLOCK

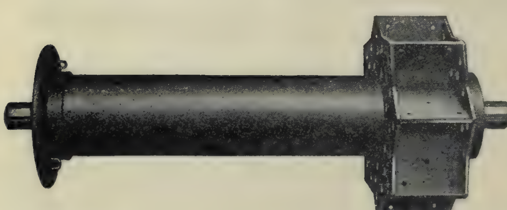


Fig. 44. R. & S. CALF-WHEEL SHAFT

Fig. 45. METAL BOX FOR SUPPORTED ENDS OF IRON BULL-WHEEL SHAFT

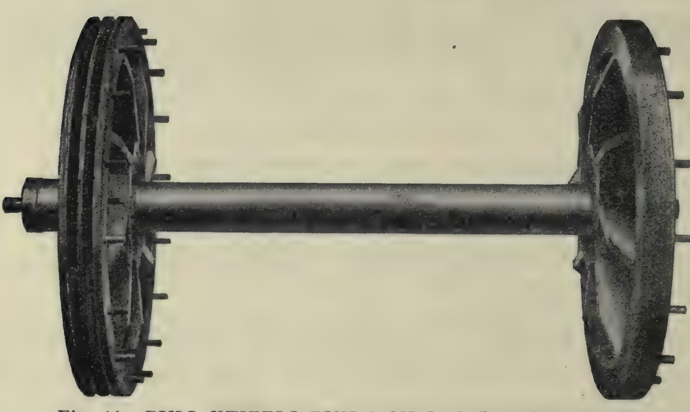


Fig. 46. BULL WHEELS BUILT ON R. & S. IRON SHAFT

construction is simple. It has a single cylinder, a simple slide valve, and link reversing gear of the locomotive type. The length of stroke is almost invariably 12 in., the cylinder diameters ranging from 8 to 12 inches. In the eastern United States 9 by 12 and in the west 10½ by 12 where the duty is heavier, are the sizes most commonly used for cable-tool work. The 12 by 12 size is frequently required

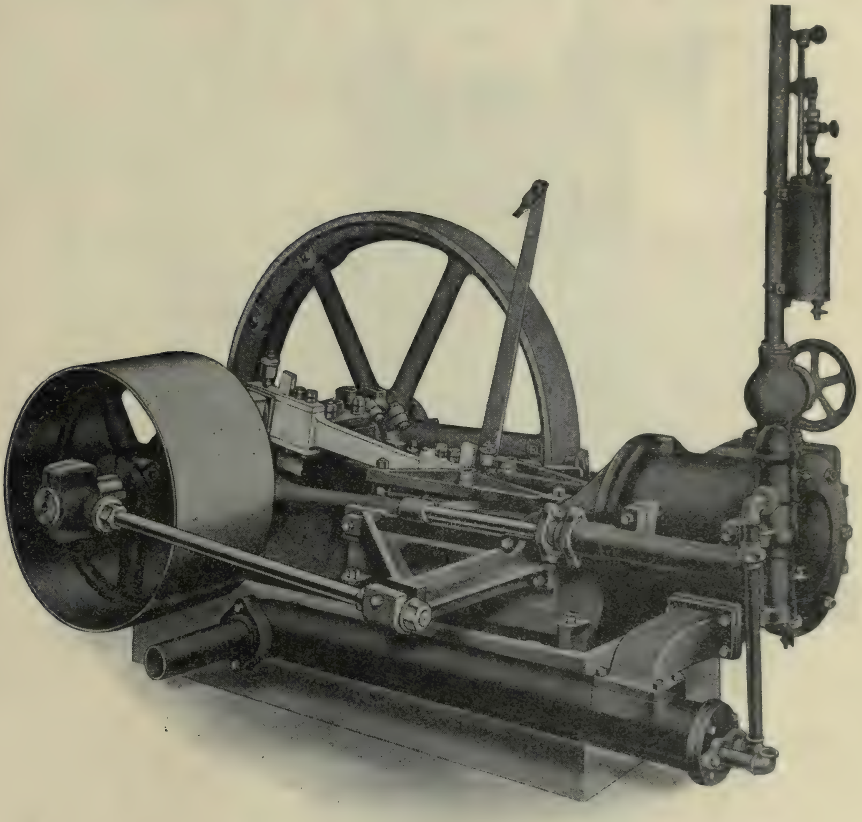


Fig. 47. IDEAL DRILLING ENGINE WITH OUTBOARD BEARING

for rotary equipments. The engine is installed so that the pulley-wheel lines with the band-wheel, and while the crank-shaft carries a fly-wheel at the other end, yet the constant pull on the belt pulley tending to work the shaft out of alignment has led to the introduction of an outboard-bearing (Fig. 47) that provides an outside supporting-box for the shaft. The weight of the flywheel may be varied by the use of removable rings or balances fastened to it with bolts to suit

the duty on the engine. Balances are usually added to steady the motion as the depth of a drilling-well increases. Pumping wells run at a low speed and the balances tend to maintain it at a uniform rate and prevent the engine from stalling on centre.

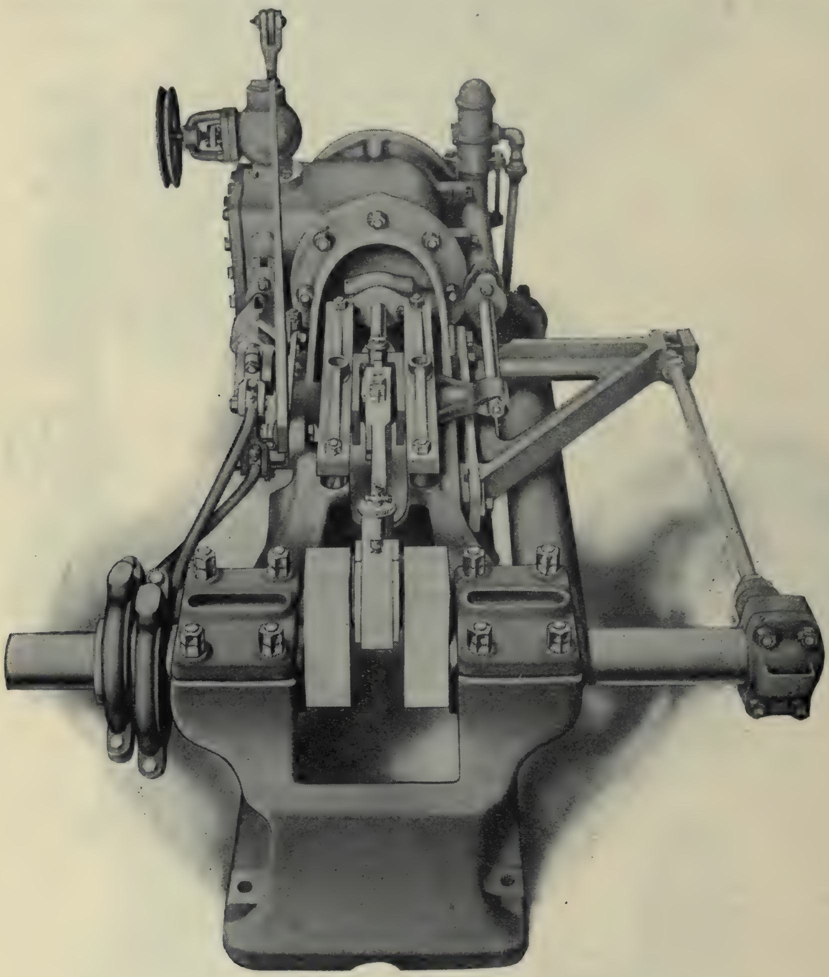


Fig. 48. IDEAL DRILLING ENGINE WITH OUTBOARD BEARING

The engine is operated from the derrick by pulling back and forth the 'telegraph cord' (42, Fig. 34), which runs from a wheel attached to the headache-post to the throttle-wheel (40). The reverse-lever is handled in a like manner by moving a ⅜ or ½-in. pipe (34) connecting it with a handle at the derrick. Usually a

simple heater is attached to the pulley side of the engine for utilizing the exhaust steam to raise the temperature of the boiler feed water. A barrel-pump, directly connected to the engine crosshead, pumps the water into the boiler. Engines are bought either stripped or complete, the former being without crosshead-pump, heater or extra flywheel balances.

As might be expected where fuel is cheap, little attention is given in the oil fields to steam economy or highly efficient boiler installations, except at the pipe-line pump-stations and the larger central station plants. These frequently have large water-tube boilers, feed water heaters, superheaters, etc., but the boilers scattered about at drilling and pumping wells are more often of simple design and installation.

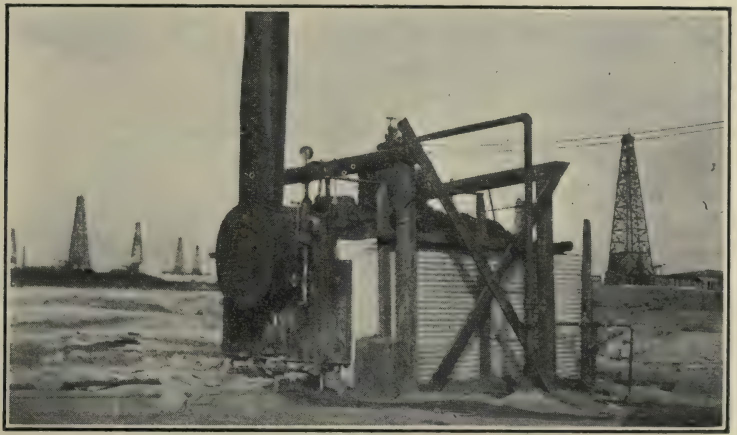


Fig. 49. BOILER MOUNTED BY HANGING FROM PIPE AND ENCASING IN OIL-SAND

For shallow drilling in some fields, light portable boilers on wheels are used. With deeper work the common horizontal fire-tube boilers of rated capacities from 30 to 45 horsepower are employed in the West for standard-tool drilling. Wells using the rotary system require larger boilers, of 70 or 80 horsepower. A simple and efficient method for setting up such a boiler is that shown in Fig. 49. This is rated at 40 horsepower, has 42 3-in. by 12-ft. tubes and is hung from two overhead stands of old 6-in. pipe and enclosed with 3000 common red brick. Corrugated iron sheets are then placed so that a space of 18 in. is left between these and the brick work. This space is filled and the top covered with heavy oil-sand that soon cakes when the boiler has been heated and assists materially in reducing the loss by radiation.

The locomotive type of firebox boilers is used extensively in the eastern part of the United States, where good boiler-water may usually be obtained. They possess the advantage that they may be quickly installed and fired, and, for this reason, find occasional use in the West, when gushers or breakdowns of regular plants bring about an urgent need for quick service; but aside from such conditions their cost and the difficulty encountered in cleaning them have prevented a more extensive use in the West, where alkaline waters cause scaling and render it necessary that boilers be frequently cleaned.

Of course the fuels used are nearly always either oil or gas, except with wildcat wells remote from a field. In burning oil, efficiency is largely a matter of proper atomization, accomplished by the use of live steam. Fig. 50 illustrates a form of burner in common use that

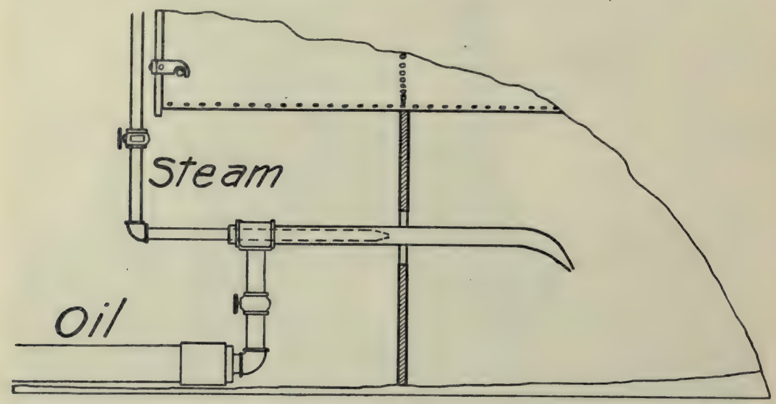


Fig. 50. OIL BURNER FOR STEAM BOILERS

may be made of ordinary materials. The live steam coming from the pointed end of the ½-in. steam-line inside the 1-in. oil-line atomizes the oil and the two together pass out of the burner through a long, narrow slot, deflected downwards in order to keep the direct flame from impinging on the boiler sheet. The exact position of the pointed end of the steam-line inside that carrying the oil is found experimentally, and so adjusted that it serves to regulate the fire automatically. As the pressure in the boiler increases a greater volume of steam is forced from the end of this pipe, retarding the flow of oil and decreasing the heat applied under the boiler. When the pressure has fallen off, as a result of the lessened heat, more oil finds its way to the burner and the heat increases.

When gas is used instead of oil its maximum fuel value is obtained only by securing the proper mixture of gas and air, so that

the flame is a clear blue in color with as little yellow as possible. Several types of burners are manufactured that may be regulated so as to obtain a perfect mixture. A simple burner may be made by placing the gas-line inside of a larger pipe, as is done with the steam pipe in the oil burner. The larger pipe has a number of holes drilled in it through which the air for mixing with the gas is admitted. Still another burner is that shown in Fig. 51, by which the gas and air before igniting mix in the larger pipe, set in brick work.

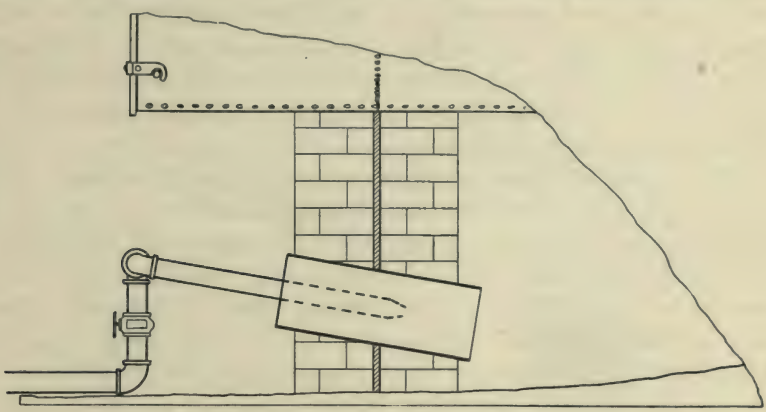


Fig. 51. GAS BURNER FOR STEAM BOILERS

For carrying steam from the boiler to the engine a 2-in. line usually suffices for standard tool work, but where the drilling is being carried on by the rotary or circulating methods, this is increased to 3 inches.

Lubrication of steam cylinders is accomplished by the use of some of the various forms of pressure-lubricators, either directly at the rig or, when a central plant supplies steam for a number of wells, from a lubricator at the plant. The latter method is unquestionably the more economical and efficient as it insures complete atomization of the heavy cylinder oil. When smaller lubricators at each well are used, a considerably smaller amount of oil is required if the small pipe carrying the oil from the lubricator into the steam-line is not merely tapped into the steam-line but is carried half the distance across the inside, and then turned up, as in Fig. 52, so that it becomes heated and atomizes more readily before passing into the steam cylinder.

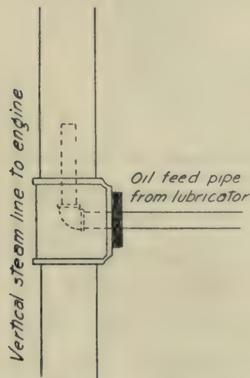


Fig. 52. METHOD OF STEAM LINE LUBRICATION

Cordage. Two classes of lines find use in drilling operations, ordinary rope made from either sisal or manila hemp, and wire rope which is built up of many small steel wires about a hemp core or centre. In the former class, which passes under the general term of 'cordage,' the cheaper rope made from sisal is employed only for general purposes about the well, while the drilling-cables and bull-ropes are of good qualities of manila hemp. Hemp rope deteriorates rapidly in very dry districts due to the fact that the hemp fibre grows only in warm and exceedingly moist climates and the moist cellular structure soon loses this moisture when brought into an arid district. It then becomes dry and brittle, loses its strength and pliability, and for this reason when not in use should be stored in as cool and moist a spot as can be found.

The individual fibers of hemp are from 6 to 10 ft. long. When manufactured into rope they are first oiled and woven into threads with a left lay, those of a lighter color and more silky texture going into the drilling cables and the more brittle, coarse and red varieties into bull-ropes. With a 2¼-in. drilling cable, 31 of such threads, each composed of many fibers, make a strand; three strands are wound with a right lay to make a rope, and three ropes, also with a right lay, compose the cable. The left lay of the fibers and the right lay of the strands and ropes, known as 'hawser' or 'cable' lay, are so made for the purpose of preventing the cable from kinking. The sizes usually employed for drilling are from 2 to 2½-in. diameter, with lengths from 1000 to 2500feet.

Weights and Lengths of Manila Cable.

Diameter.	Weight per Foot.	Breaking Strain in Pounds.
2 in.	1.58	35,430
2⅛ "	1.65	41,088
2¼ "	1.79	47,170
2½ "	2.33	53,665

Manila cables for drilling are used chiefly in so-called 'dry' holes, where the nature of the ground is such that it does not cave readily and the only water in the well is that which is placed there to assist the bit in cutting the hole, and the bailer in bringing out the cuttings. 'Wet' holes, which are filled with water to prevent the sides from crumbling, interfere with the motion of the cable and are usually drilled more advantageously with wire drilling-lines. The chief merits of the Manila line arise from its great stretch, or spring, through which, by giving the walking-beam the proper motion, a

much heavier blow may be delivered by the drilling-tools on the end of the line. The same quality in the line causes the tools to spring back quickly when the blow has been struck, thus dislodging the bit from the cuttings that tend to stick and hold it fast.

Manila lines are used almost exclusively where drilling is carried on by means of spudding, as spudding with a wire line places too severe a strain on the derrick.

Bull ropes are made with a diameter of 2½ in. and length of 90 ft. They are known as soft lay rope and consist of three strands, each strand built up of many fibers.

Wire Rope. The wire ropes in general use for drilling wells are (1) the drilling-line, wound on the bull-wheel shaft, to carry the drilling tools; (2) the casing line, wound on the calf-wheel, and used for handling casing; (3) the sand-line, which runs on the sand-reel and carries the bailer in and out of the hole. The introduction of wire rope for drilling purposes is comparatively recent but its use has spread rapidly and it is now generally employed for work at depths greater than 1200 feet. Unlike much of the material employed for well drilling, these lines have practically no salvage value when they have become unfitted for further service at the well.

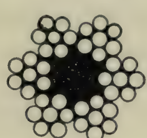


Fig. 53. SAND AND LIGHT DRILLING LINES. 6 STRAND 7 WIRE

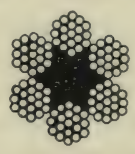


Fig. 54. DRILLING AND CASING LINES. 6 STRAND 19 WIRE

The line used for carrying the drilling tools encounters the most severe service of the three classes, and its cost is no small factor in drilling a deep well. These are in nearly all cases made of extra strong cast steel wire, of a grade intermediate in strength, hardness, and other characteristics between the regular cast steel ordinarily used in hoisting-ropes and the plow steel used where great abrasion is met. The construction of the line varies with the drilling conditions.

In the eastern fields, where the duty is light, the ropes are composed of six strands of seven wires each, with a hemp centre (Fig. 53). In other fields various combinations of six strands of 12 wires, 4 strands of 5 wires, 6 by 25, 6 by 15, etc., have been tried with varying results, mostly unfavorable, and for heavy work, the general construction has apparently settled down to the use of the standard hoisting-rope construction of 6 strands of 19 wires each, with a hemp

centre of approximately the same diameter as each of the strands, or increased only enough over this to afford a proper cushion to the wire strands and prevent them from bruising or abrading each other (Fig. 54). They are put up almost invariably with a left lay, although there appears no particular reason for this, and some operators use right lay with good success.

Sizes and Strengths of Drilling Lines.

3/4 in.	20.2 tons
7/8 "	26.0 "
1 "	34.0 "
1 1/8 "	43.0 "
1 1/4 "	53.0 "

In standard engineering practice a factor of safety of 5 to 1 is used to obtain the working load of a wire rope, but in drilling service the tensile strength of a line means little, for every drilling line is almost certain to be subjected at more or less frequent intervals to a load closely approximating its ultimate strength; and since the elastic limit of steel is about 60% of its total strength the application of loads beyond this critical point, even though infrequent and of short duration, will tend to change the character of the steel and shorten its life, which would otherwise be determined by the normal conditions of abrasion, etc.

No set rule obtains for deciding the proper size of line for any particular well or drilling conditions and operators follow individual tastes as to the one best suited to their needs. For fairly light work the ¾ in. and ⅞ in. are in common use. Deeper drilling and heavier tools require a 1-in. line, and recently considerable attention has been given to a study of the economic advantage of using extremely heavy tools and a 1½-in. line, under drilling conditions of such a nature that the time-factor and saving in labor-cost warrant the added expense of these heavier materials. Neither is it possible to state, except within very broad limits, the amount of drilling that may be expected of a line. Under favorable conditions a light line may serve for the drilling of several 1000-ft. holes, while a heavier line in ground that is more severe on it may become worn out in a few hundred feet of drilling. Fishing for lost tools and jarring on casing with a spear are especially trying, and a line deteriorates rapidly in such work.

Lines are shipped from the mills on heavy reels and when received at the well are prepared for unwinding by placing a pipe through a centre opening in the reel and blocking up the end of

this pipe so that the reel may turn on it. One end of the line is pulled up over its pulley in the crown block, then down and fastened to the bull-wheel shaft and the line wound on the shaft by engine power. A space about 30 in. long at the centre of the shaft, with a frame built up at each end, is used to spool that part of the line in immediate use, the remainder being carried at one end of the shaft, with left-lay lines preferably at the end opposite the brake-band.

The practice of uncoiling a line from the shipping reel by placing the latter on its side and driving a stake in the ground to hold it in place while being turned places an undue strain on the line by reason of the tendency to kink, and should not be permitted. Particular care should be taken when handling lines to prevent kinks by using as large snatch blocks as possible. Frequently lines are moved from one rig to another, not by coiling on reels and hauling them, but by pulling one end of the line to the new rig and coiling it directly from one shaft to the other. Unless pains are taken to prevent it the line may not kink but will 'dog-leg,' that is, suffer a small sharp bend. In such a case the line at this point never becomes absolutely straight; and it soon weakens from wearing on the side of the casing or hole and must be cut and spliced. The splice usually employed with drilling lines is that known as the 'blind' splice, in which the strands of each end of the line are opened for about 15 ft., the hemp core extracted and the strands woven together again, with one of the strands taking the place of the core.

In some fields a unique combination of wire and manila lines has been found very successful for drilling. It is known as the 'cracker' line and consists of about 100 ft. of manila rope spliced on the end of a wire line nearest the drilling tools. In this way the benefit of the spring and stretch in the manila rope is obtained without the expense of running a line composed wholly of such rope, with the further advantage that it may be used in a 'wet' hole.

Casing-lines in almost all cases are standard hoisting ropes of cast steel wire, composed of 6 strands of 19 wires, right lay, with a hemp centre.

Tensile Strengths of Casing Lines.

5/8 in.	12.5 tons
3/4 "	17.5 "
7/8 "	23.0 "
1 "	30.0 "

All the above sizes find use in different districts and it is probable that the factor of safety of 5 to 1 is rarely exceeded. The ⅞ and 1-in. sizes of this type are also used as hoisting ropes at rotary wells. After they have become worn so that they are unsafe for pulling casing they are used for tubing lines, for handling tubing and sucker-rods in producing wells.

Sand lines are identical with the standard coarse laid, transmission, or haulage rope. Like casing lines they are of cast steel wire, right lay, but differ from them in being composed of 6 strands of 7 wires each. They differ in construction because they are not subjected to short bends, but do meet considerable abrasion while traveling in and out of the hole, and the smaller number of coarser wires gives a longer life to the line and a lower first cost.

Tensile Strengths of Sand Lines.

3/ 8 in.	4.6 tons
1/ 2 "	7.7 "
9/16 "	10.0 "
5/ 8 "	13.0 "

Casing. In drilling where the ground is rocky and firm or where the materials in the series of strata are bound together so that fragments do not cave in from the walls of the hole, the drilling may frequently be carried for hundreds of feet in 'open hole.' More often, however, the beds of clay, shale and sands, with some of them containing water, are so fragile and loose that they crumble and fall in to such an extent that drilling operations must be discontinued unless they can be held back. In such ground there is always the further danger of the cavings burying the drilling tools. These conditions have led to the adoption of various forms of tubes for lining the hole. A second and very important feature of the value of such linings is their use for excluding from the oil-sands the water held in strata nearer the surface and which, if not prevented from entering the oil sand, will displace the oil by reason of its greater specific gravity and eventually ruin the well.

Casing as now used in the oil fields is made of either iron or steel and the kinds and sizes differ considerably with the conditions obtaining in different parts of the world. The complete column of pipe as placed in the well is known as the 'string' of casing and in some fields one string suffices to finish the well. More often, if any considerable depth is attained, the pressure (commonly known as the 'friction') of the crumbling materials against the pipe becomes

so great that the pipe is bound tight and cannot be moved farther either up or down. A second string, small enough to go inside the first, must then be put in before drilling is continued; and frequently four or five, or even more, may be necessary in reaching depths of over 2000 ft. in difficult ground.

For the first well drilled in unproved ground, the number of strings of pipe that will be required in reaching a certain depth is unknown; but in a field that has been drilled and the drilling conditions learned, the starting-size becomes merely a question of the size with which it is desired to finish the well. Strings of 10-in. and 8¼-in. pipe are sufficient in some American fields, while with others the well will be begun with 18-in. casing. In Russia, where the sands cave badly, holes are started with a diameter of 36 in. in order to finish them 16 inches.*

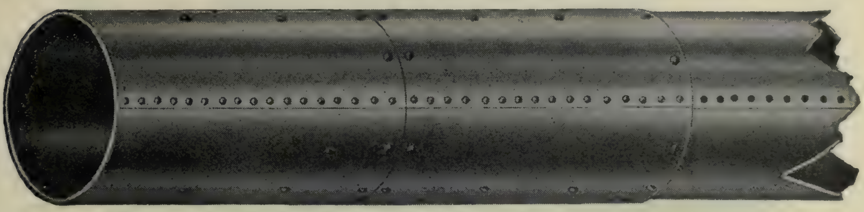


Fig. 55. RIVETED STEEL DOUBLE WELL CASING

Two general classes of casing are in common use for oil-well service—riveted steel pipe and screw casing. Riveted, or 'stovepipe,' casing is made of steel or iron sheets, riveted at the seams, and is used especially for the first string to be inserted in a well. It is made by cutting the sheets into the proper size, punching and countersinking the rivet-holes, then rolling to shape and fastening with rivets. The pipe most commonly used in the United States has two thicknesses of sheets, so placed with respect to each other that the end of one sheet is set opposite the centre of the other, so that at the end of a joint the inside sheet projects for half its length beyond the outside sheet, leaving a corresponding recess at the other end (Fig. 55). This double-riveted casing is made in joints 2 or 3 ft. in length, and, for ease in handling, several of these joints are riveted together into sections of from 10 to 21 ft. before placing in the well.

*A. Beeby Thompson, Petroleum Mining, p. 238.

Sizes and Gauges of Double-Riveted Pipe.

Gauge No.	Thickness in Inches.	Diameter	12	13	14	15	16	18	20
8	0.172	Wt. lbs. per foot			54	57	62	70	76
10	0.141	"	41	44	46	48	51	57	60
12	0.109	"	30	32	34	36	39	43	47

Frequently the pipe is 'picked' before inserting it in the well. This consists in denting the outside with a heavy sharp-pointed pick, and is done to take up any slack between the outside and inside sheets and assist the rivets to prevent it from pulling apart. Since nearly all casing is driven from the surface before reaching its final depth, it is advisable to place on the bottom of the first, or 'starter' joint, a steel shoe of slightly greater diameter than the outside of the pipe itself (Fig. 56). This cuts away any irregularities projecting from the side of the hole and clears a passage

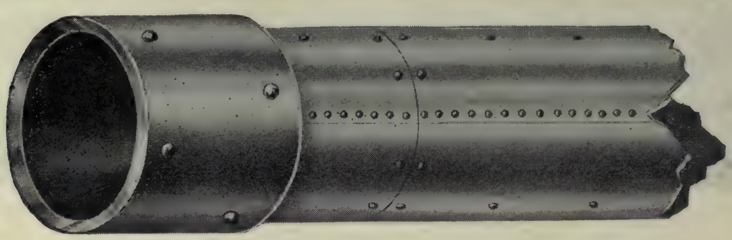


Fig. 56. RIVETED STARTER-JOINT WITH DRIVE-SHOE

for the casing. Stovepipe casing shoes are made from 3 to 14 in. in length and are riveted directly to the starter joint. The latter is usually made of three thicknesses for the first 18 ft., and when a steel shoe is not used, the innermost sheet is lapped back over the outside for 6 or 8 in. and riveted there. This is known as the 'turnback' starter and while it is not as rigid as the solid steel shoe and does not contribute as well to the strength of the starter-joint it has the advantage of a smaller outside diameter, thus reducing the size of hole to be drilled by the cutting tools.

The merits of riveted pipe are mainly that its smooth, uniform outside surface is a great aid in carrying the casing down through loose and sandy materials which tend to fall in and bind against the couplings on screw casing. Screw casing, however is more easily handled and may be raised and lowered at will, while the riveted pipe, when once started in the hole, is not raised and can be lifted out only by the use of a spear.

Screw casing is made of either iron or steel plates, welded at the seam, and takes its name from the threads that are cut at each end of the joint. With the exception of a few types, a threaded sleeve, or coupling, connects two joints by screwing over the threads at the ends. Couplings are invariably made of iron, but the pipe itself may be obtained of either iron or steel and individual tastes or ideas of operators rather than any specific drilling condi-

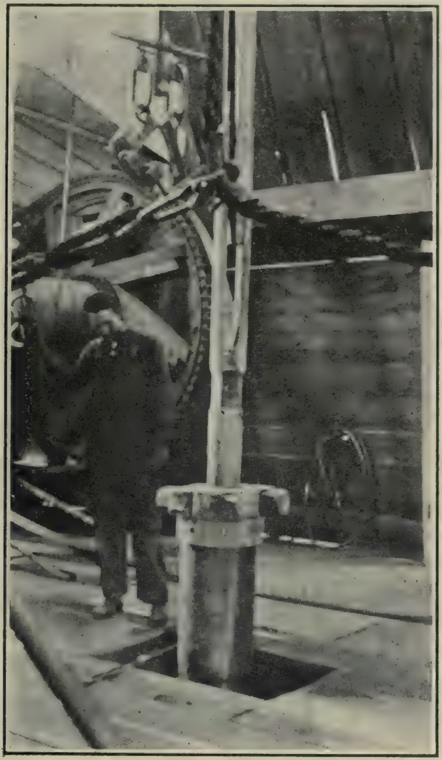


Fig. 57. DRIVING STOVE-PIPE, SHOWING DRIVE-CLAMPS FASTENED TO THE STEM

tions usually govern which is used. Steel has the advantage of a slightly lower cost and is said to be stronger than iron. It is, however, more subject to weakness with age from the chemical and electrolytic action of alkaline and sulphur waters.

Screwed pipe is manufactured by rolling the ingots of metal into slabs and rolling the slabs again into plates of the proper length, thickness and width according to the size of pipe desired. The plates, known as 'skelp,' are then bent to circular form and welded.

In the latter stage, two different processes are followed by which are made either the lap-weld or the butt-weld pipe. The butt-weld is made by placing the two edges together as shown in Fig. 58; in the lap weld, before the skelp is bent the edges are scarfed so that when they are overlapped a much larger welding surface is obtained than with the butt-weld and a stronger bond insured at the weld. For this reason little butt-weld pipe is used for casing, although all ordinary low-pressure line-pipe for surface lines is made by this process.

Each size of pipe has an accepted standard weight, and when stronger and thicker pipe of this size is made for heavier duty, the additional metal is placed on the inside, reducing the actual inside diameter but retaining the same outside measurements. Thus the so-called 6¼-in. casings weighing 20, 24, 26 and 28 lb. per ft. all have the same outside diameter of 6.625 in., but internal diameters

Fig. 58. BUTT WELD LAP WELD

of 6.049, 5.921, 5.855 and 5.791 respectively. Permissible variations are 5% above and below the rated dimensions. The casing comes from the mills in random lengths ranging around 20 ft., and one make may also be obtained in lengths of 35 and 40 feet. These long joints are thought to be an advantage in reducing the friction of cavings against the collars, but the inconvenience in handling them has rather retarded their adoption.

Since it is desired, when more than one string of casing is necessary to finish a well, to reduce the bore of the hole as little as possible, a sequence of sizes is used so that one string will barely pass inside the next larger without unnecessary friction. The usual practice with both riveted pipe and screw casing is to use sizes that result in a loss of approximately 2 in. with each succeeding string. Wells using the larger sizes of riveted pipe may contain strings of 24, 22, 20 in., etc., and those with screw casing may have 10, 8¼, 6¼ in., etc. In many cases a combination of the two may be employed so that a casing record shows 18 and 16-in. stovepipe, with 12½, 10 and 8¼-in. screw casing; or 15½-in. screw casing; 13-in. stovepipe, and 10 and 8¼-in. screw-pipe, all depending on the drilling conditions and personal preferences of the operators.

An idea of the range of sizes and weights of screw casing made may be obtained from the following table showing those manufactured by one firm.*

Dimensions of Screw Casing.

Size	Diameters		Thickness	Weight per foot		Couplings		
	External	Internal		Plain ends	Threads and Couplings	Diameter	Length	Weight
5⅝	6.000	5.352	.324	19.641	20.000	6.765	7⅛	15.748
6¼	6.625	6.049	.288	19.491	20.000	7.390	7⅝	18.559
6¼	6.625	5.921	.352	23.582	24.000	7.390	7⅝	18.559
6¼	6.625	5.855	.385	25.658	26.000	7.390	7⅝	18.559
6¼	6.625	5.791	.417	27.648	28.000	7.390	7⅝	18.559
6⅝	7.000	6.456	.272	19.544	20.000	7.698	7⅝	17.943
6⅝	7.000	6.276	.362	25.663	26.000	7.698	7⅝	17.943
6⅝	7.000	6.214	.393	27.731	28.000	7.698	7⅝	17.943
6⅝	7.000	6.154	.423	29.712	30.000	7.698	7⅝	17.943
7⅝	8.000	7.386	.307	25.223	26.000	8.888	8⅛	27.410
8¼	8.625	8.017	.304	27.016	28.000	9.627	8⅛	33.096
8¼	8.625	7.921	.352	31.101	32.000	9.627	8⅛	33.096
8¼	8.625	7.825	.400	35.137	36.000	9.627	8⅛	33.096
8¼	8.625	7.775	.425	37.220	38.000	9.627	8⅛	33.096
8¼	8.625	7.651	.487	42.327	43.000	9.627	8⅛	33.096
9⅝	10.000	9.384	.308	31.881	33.000	11.002	8⅛	38.162
10	10.750	10.054	.348	38.661	40.000	11.866	8⅛	45.365
10	10.750	9.960	.395	43.684	45.000	11.866	8⅛	45.365
10	10.750	9.902	.424	46.760	48.000	11.866	8⅛	45.365
10	10.750	9.784	.483	52.962	54.000	11.866	8⅛	45.365
11⅝	12.000	11.384	.308	38.460	40.000	13.116	8⅛	50.445
12½	13.000	12.438	.281	38.171	40.000	14.116	8⅛	54.508
12½	13.000	12.360	.320	43.335	45.000	14.116	8⅛	54.508
12½	13.000	12.282	.359	48.467	50.000	14.116	8⅛	54.508
13½	14.000	13.344	.328	47.894	50.000	15.151	9⅛	67.912
15½	16.000	15.198	.401	66.806	70.000	17.477	9⅛	98.140

Several different kinds of screw casing are made for well work and the various forms differ somewhat in the sizes of collars, number of threads to the inch, etc. While the threads on ordinary line-pipe in the sizes over 2½ in. nearly always number eight to the inch, this number has been found to take too much stock from the pipe at the threads to sustain the enormous weights of long strings of heavy casing, and 9, 10, 11½ and 14 threads have all been tried. The 11½ and 14 thread cuts have been found to be so small that they permit the pipe to pull apart quite easily and present practice

*Book of Standards, National Tube Company, page 29.

seems to have dropped back to the 10 thread for the greater portion of casing now made.

As a rule, the collar thread does not start at the end of the collar, but begins from the end of a recess cut so that when the pipe has been screwed together the end of the collar fits snugly over the pipe and increases the rigidity of the completed string. The length of thread is usually from 3 to 3½ in., with sufficient taper to insure a tight bond with the collar. The space inside the collar between the two ends is customarily from ¼ to ½ in. after the joints have been screwed together. Pipe that is to be subjected to exceptionally heavy driving is made so that the ends of the joints meet, and is known as 'drive pipe' (Fig. 59). Usually these threads have no taper and are cut coarser than the 10 thread of ordinary casing since butting the ends relieves the couplings of much of the strain. Drive pipe has small value for use where the ground caves into the hole to any extent, as after it has been driven severely it becomes

Fig. 59. DRIVE-PIPE

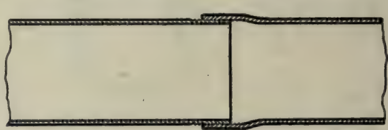


Fig. 60. INSERTED-JOINT CASING

weakened at the threads and pulls apart readily when a strong pull is applied.

Inserted-joint casing (Fig. 60) is sometimes placed in a hole where a small reduction of bore is desired rather than the greater strength of coupled pipe. It is made by swelling out one end of the joint and cutting this with an inside thread so that it screws over the outside thread end. The threads are usually 11½ to the inch.

As with riveted pipe, a steel shoe is placed on the lower end of the first joint in a string of casing (Fig. 61), and having an outside diameter slightly greater than that of the couplings so that the beveled cutting-edge insures a path large enough for the passage of the pipe and couplings (Fig. 62). The Baker shoe (Fig. 63) is made with a number of open spaces in the cutting end, and is a material improvement where conditions are such that the pipe is to be worked down through hard ground. When strings of casing are to be inserted in holes already drilled by the rotary method, a type of shoe having a saw-toothed end is frequently used. Any

slight projections from the side of the hole encountered while lowering it are cut away by turning the pipe and milling off the irregularities with the shoe.

All casing is presumably tested at the mill before shipping and is supposed to stand the internal test-pressure marked on the pipe. It is rarely, however, that pressure from the inside is at all important in well drilling operations, although the external or collapsing pressure is often of vital importance. The most severe strain of this nature comes, after the water has been excluded by cementing or otherwise, when the well is bailed dry on the inside

Fig. 61. PLAIN CASING-SHOE

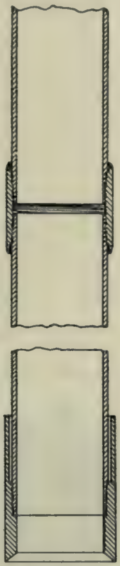


Fig. 62. SCREW CASING WITH CASING-SHOE

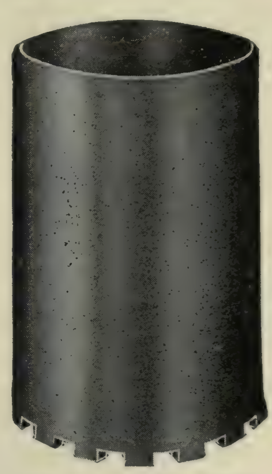


Fig. 63. BAKER SHOE

for the purpose of learning whether or not the attempt to shut off the superficial water was successful. The collapsing pressure exerted against the pipe at this time is represented by the difference between the heights at which the fluids stand on the outside and the inside.

The following table* has been computed, from data determined by a great number of artificial tests on the collapsing pressure of casing, for the purpose of supplying an approximate idea as to the limit of depths to which casing may safely be carried under a factor of safety of 2, which while small yet seems to be warranted by the results of actual experience in the fields.

*Collapsing Pressure of Steel Tubes, R. S. Hazeltine, *Western Engineering*, July, 1912.

TABLE SHOWING COLLAPSING PRESSURES OF LAP-WELDED STEEL CASING FOR SIZES COMMONLY USED IN CALIFORNIA.

Size, inches	Weight per Foot, pounds	Inside Diameter, Inches	Outside Diameter, inches	Thickness, inches	Collapsing Pressure, pounds per square inch	Equivalent Water Column, feet	Water Column Factor of Safety 2, feet
4½	15.0	4.500	5.000	0.250	2944	6790	3395
5⅝	20.0	5.370	6.000	0.315	3160	7280	3640
6¼	20.0	6.000	6.625	0.312	2704	6230	3115
	26.0	5.845	6.625	0.390	3717	8560	4280
	28.0	5.775	6.625	0.425	4167	9600	4800
6⅝	20.0	6.437	7.000	0.281	2096	4830	2415
	26.0	6.312	7.000	0.344	2867	6600	3300
	28.0	6.220	7.000	0.390	3440	7930	3965
7⅝	26.0	7.390	8.000	0.305	1914	4410	2205
8¼	28.0	8.015	8.625	0.305	1680	3870	1935
	32.0	7.935	8.625	0.345	2080	4790	2395
	36.0	7.875	8.625	0.375	2383	5490	2745
	38.0	7.765	8.625	0.430	2928	6750	3375
	43.0	7.625	8.625	0.500	3638	8380	4190
9⅝	33.0	9.500	10.000	0.250	780	1800	900
10	40.0	10.000	10.750	0.375	1638	3770	1885
	48.0	9.850	10.750	0.450	2234	5150	2575
	54.0	9.750	10.750	0.500	2643	6090	3045
11⅝	40.0	11.437	12.000	0.281	641	1475	737
12½	40.0	12.500	13.000	0.250	402	927	463
	45.0	12.360	13.000	0.320	745	1717	858
	50.0	12.250	13.000	0.375	1109	2560	1280
13½	50.0	13.250	14.000	0.375	936	2160	1080
15½	51.3	15.416	16.000	0.292	314	724	362

Fig. 64. A GUSHER

CHAPTER IV.

DRILLING METHODS.

The two principal modern methods of drilling oil wells are (1) by the standard or percussion method, and (2) by the rotary flush system. There are several modifications and combinations of the two, but nearly all drilling is done by one or the other. The principle of the percussion system is that of raising and dropping a heavy stem and bit on bottom, afterwards removing the drillings, which have been mixed with water by a bailer. The rotary has been described as an auger with water connections which wash the debris from bottom by the action of a pump.

The rotary cannot be successfully used in hard strata of limestone, sandstone or slate, and for this reason its use is confined to those localities in which the principal formation includes shales, clays and sand interspersed with occasional shells of harder material. On the other hand, the standard rig does not work satisfactorily in running or heaving sand, or in heavy gas pressures, and is therefore used in such formation only in connection with the rotary. For any particular locality, however, one or the other systems or their combination will be found to perform the drilling in a capable manner.

Standard Method. When the derrick has been erected by the rig builders, the drilling crew of four men (two drillers and their tool-dressers) take possession and prepare to start drilling or 'rig up' as it is called. It is usual to excavate a cellar 8 by 10 by 20 ft. directly under the derrick floor in order to facilitate the handling of the casing as well as to give freedom of action to the temper-screw. The cellar can be sunk by hand or, when desired, a hole from 100 to 200 ft. deep is drilled and the earth thrown into it and there redrilled and bailed out, thus providing a means of its removal. A sump is excavated by scrapers near the derrick and a dump-box installed under the floor for conveying the drillings from bailer to sump. The sump is often used for an oil reservoir later on when the well is producing quantities of oil and sand. A forge is placed

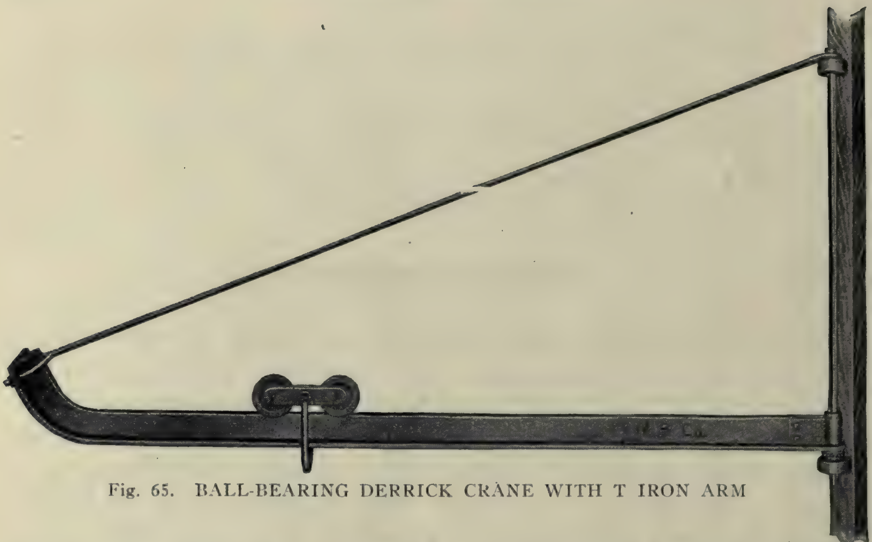


Fig. 65. BALL-BEARING DERRICK CRANE WITH T IRON ARM

on the right side of the derrick floor for heating the bits to draw them out to guage, while a crane (Fig. 65) with a chain hoist is so placed as to swing a bit into the forge or to suspend the bit or

Fig. 66. TRIPLE SNATCH BLOCK FOR CASING-LINE

Fig. 67. TUBING AND CASING HOOK WITH CLEVIS

other equipment for connection to the drilling-tools. A lagging of manila cable is wound tightly around the band-wheel and spiked every 8 or 10 in. to prevent its being torn off. The band-wheel has been previously machined on the face, if necessary, with a turning-bar. A 12-in. 6-ply stitched belt transmits power to the band-wheel

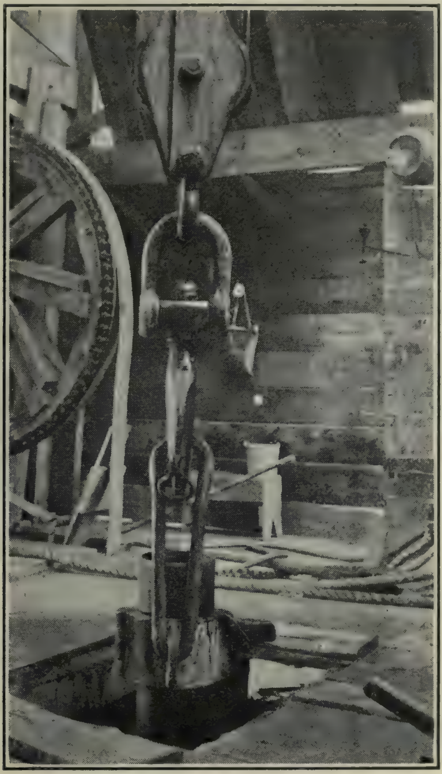


Fig. 68. LIFTING CASING, SHOWING ELEVATOR, CASING-HOOK AND BLOCK

from the drilling-engine, and provision is made to align the two by shifting the engine upon its foundation. The shaft of the calf-wheel is also lagged to prevent its being cut by the wire-line as well as to provide a larger diameter for the casing-line to wind upon.

The sprocket chain which turns the calf-wheel from the band-wheel is put on and a clutch fitted for convenient manipulation by the driller when standing near the throttle at the headache-post. The casing-line is passed over the four casing-sheaves on top of the derrick and threaded through the 32-in. triple casing-block (Fig. 66), from which hangs a heavy casing-hook (Fig. 67), 5 to 7½ in.

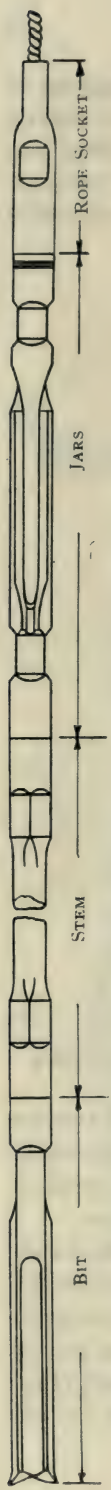


Fig. 69. STRING OF DRILLING TOOLS

diameter. In moving casing, the links of the elevator are placed over the casing-hook, the body of the elevator taking hold under the top coupling of the pipe. The clutch is thrown in and the pipe raised or lowered by the calf-wheel. The sand-reel lever is placed near enough to the throttle-wheel on the headache-post to permit of the driller handling both at the same time, while powerful brakes are placed on the calf and bull-wheels. The sand-line is drawn on the double-drum sand-reel, the manila cable is wound on the bull-wheel, after which the drilling tools are pulled into the derrick and coupled together.

A complete string of drilling tools consists (Fig. 69) of a rope-socket, jars, stem, and bit, in the order

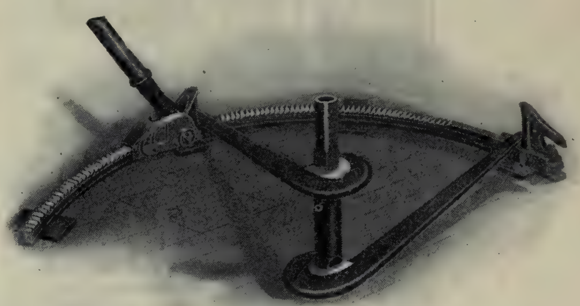


Fig. 70. BARRETT JACK AND CIRCLE

named. They are screwed together by means of a powerful jack operated on a circular track (Fig. 70), and two men are required to tighten the larger joints. The latter, which are tapered to make coupling easier and to protect threads, are made of soft annealed steel and have a shoulder about 1 in. wide which prevents them from unscrewing when in the well. When the joints are new, they come within $^1/_{16}$-in. shouldering by hand, and should be set up by the jack and unscrewed several times before put to actual use, to prevent any danger of unscrewing. They should at all times be thoroughly cleaned to remove grease or rust, and the shoulders should be free from rough or broken places. The threads often become cupped

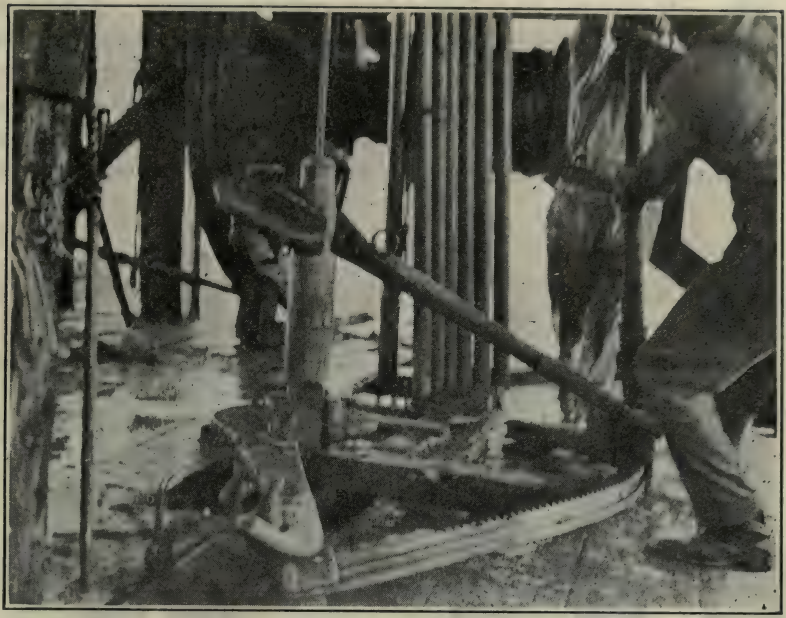


Fig. 71. TIGHTENING A ROPE-SOCKET ON A STRING OF STANDARD CABLE DRILLING TOOLS

from faulty joints or excessive tightening, in which case they should be sent to the shop for re-threading. In the larger sizes of tools, the joints are 4 in. at the base, 3 in. at the top, with 7 threads to the inch, and are called 3 by 4-7 joints. They are 6 in. outside diameter, and the wrench-squares for tightening are placed close to them. Similarly 4 by 5-7, 2¾ by 3¾-7, 2 by 3-7, 1¾ by 2¾-8, are the sizes used, depending upon the diameter of the casing and the formation being drilled. Care should be exercised in setting up the smaller joints, as the pins are sometimes twisted off. The rope-socket for manila cable has a 2½-in. hole bored through the top and tapering at the side about 12 in. below (Fig. 72); the end of the cable is pulled through the bore and interlaid with short pieces of manila rope. When pulled tightly into place, by weight of the tools, a wedge is formed making an effective connection. The wire-line socket (Fig.73) has a 1⅛-in. hole bored through to the box, with a recess above the latter; the line is thrust through this hole from the top, the ends are turned back and pulled into the recess and hot babbitt poured in, preventing the line from pulling out of the socket.

The drilling-jars (Fig. 74) are generally not used until the hole is 150 ft. deep or more. They resemble two great links of a chain with about 16-in. stroke for ordinary drilling. When the tools become fast from cavings or any other cause, the jars, by lowering the temper-screw, are slacked sufficiently to deliver a sharp upward blow, eliminating the strain on the drilling-line, which would occur

Fig. 72. ROPE-SOCKETS
Babcock for Wire Cable — New Era or 'Wood-pecker' for Manila Cable — Babcock Sub for Wire Cable

Fig. 73. UNION RATCHET ROPE-SOCKET FOR WIRE-LINE

if pulling were resorted to. In ordinary drilling, the jars are not brought into action, but remain extended to their full stroke. The stem (Fig. 76) with 3 by 4-7 joints is usually 4½ in. by 28 ft. long, and a complete string of tools of this size weighs about 4000 pounds.

In districts where the formation is slate, limestone or sandstone, it is usual to dress the cutting-edge of the bit more or less to a chisel point in order to make faster headway in the hard rock, while in soft formations of clay, shale or sand, the centre of the bit is cut out, making a concave surface with the outer edges from 1 to 3 in. longer than the centre. In either case, all four corners are drawn out to gauge and the cutting-edges properly rounded off to conform to the size of the casing used. In California, the shank

of a drilling bit should be smaller than the cutting edge by 1 or 2 in., thus affording an offset by which a larger hole can be cut than with a straight bit. In soft formations, a chisel-bottom bit will dig faster than the drillings can be mixed with the water, making it necessary to re-drill the debris in order entirely to re-

Fig. 74. DRILLING JAR

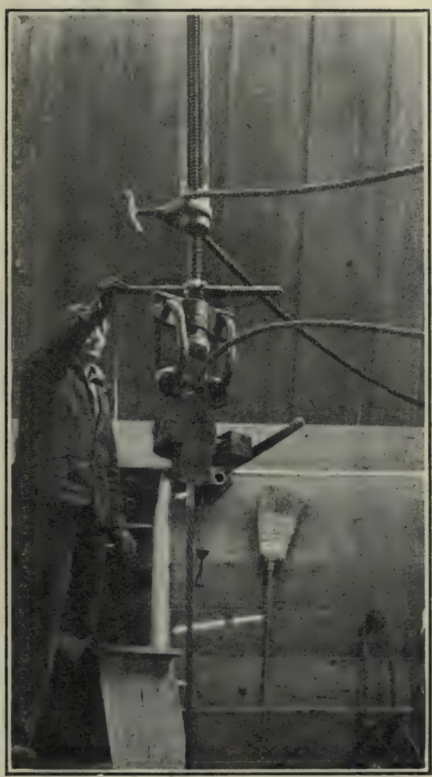


Fig. 75. DRILLING WITH WIRE-LINE SHOWING TEMPER-SCREW

move it from the hole, while a concave bit is totally unsuited to hard formation, as a sharp, cutting edge is desired. Bits are dressed, therefore, to suit the formation. Large water-courses are provided in the California style of bit (Fig. 77), which mixes the water more freely with the drillings; some operators prefer

Fig. 76 AUGER STEM

the 'Mother Hubbard' pattern (Fig. 78), as the square shoulders help in mixing the mud, and when this bit unscrews or is lost, usually stands straighter in the hole than those with a rounded shoulder, making its withdrawal much easier. The occasion often arises where the use of the under-reamer is impossible for reaming

Fig. 77
DRILLING BIT
Ordinary California
Pattern

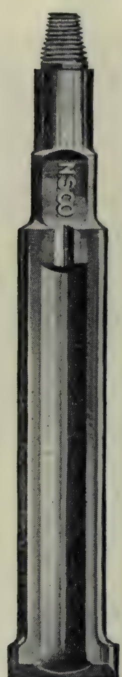


Fig. 78
DRILLING BIT
'Mother Hubbard'
Pattern

Fig. 80
DOUBLE UNDER-REAMER
Showing Cutters Contracted to Enter Casing

Fig. 79. DOUBLE UNDER-REAMER
Expanded as in Operation

a hard formation or shell, in which case a bit can be dressed 'sidehill,' that is, with one lug or cutting edge drawn out 1 to 2 in. larger than gauge, while the other edge is beaten in somewhat, making a one-sided tool which cuts a larger hole than would the ordinary bit. Sidehill bits are often used when drilling in stove-pipe casing where the under-reamer cannot be used.

The under-reamer (Figs. 79, 80, 81, 82) is a specially designed tool which, as its name implies, is used to ream or enlarge the hole below the casing and is employed constantly in wells where it is desired to carry the strings of pipe for long distances. The California under-reamers are reliable in construction and action; they have two lugs or cutters, which, when fully expanded, will cut a larger hole than would the casing-shoe, giving the casing ample room between the walls. A 10-in. under-reamer, for instance, will cut a 13½-in. hole, while the 10-in. shoe is 12 in. diameter, leaving a space of 1½ in. These cutters are held in place by a powerful spring and can be pulled down to a smaller diameter than the inside of the pipe. When its use is required, the bit is removed and the under-reamer attached to the stem, the cutters are pulled together on the derrick floor by the driller, and the string of tools lowered in the well. Upon emerging from the shoe, the spring ex-

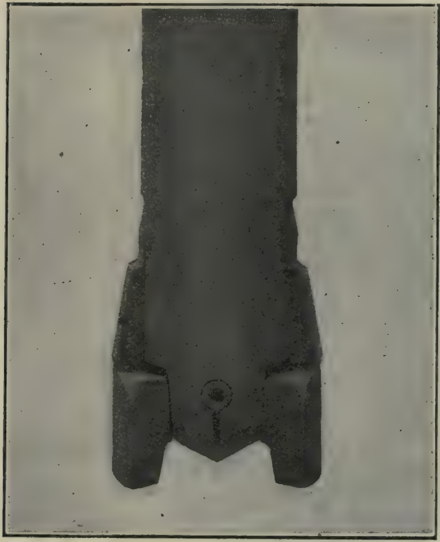


Fig. 81. LOWER END OF WILSON UNDER-REAMER

Fig. 82. WILSON UNDER-REAMER

pands the cutters back to a shoulder on the body of the under-reamer. Then they are ready for work. Upon being withdrawn, the cutters strike the shoe and are pulled together, after which the

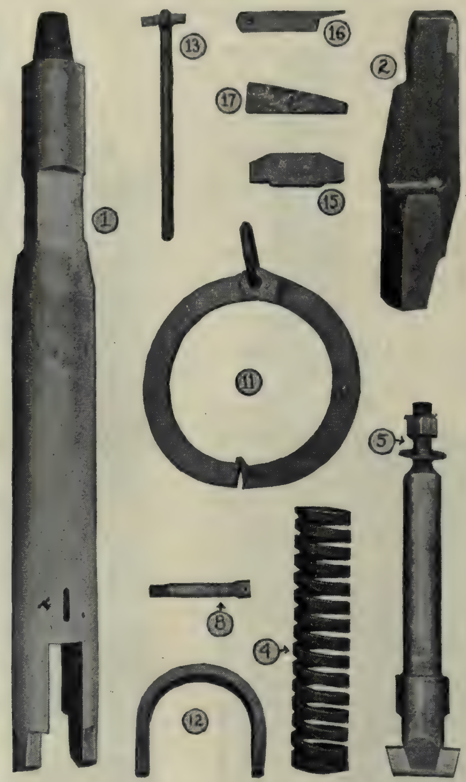


Fig. 83. PARTS FOR WILSON UNDER-REAMER

tools can be raised to the surface. The wrenches (Fig. 84) for setting up the joints are massive, weighing from 250 to 450 lbs. each, and are usually counterbalanced by weights suspended outside of the derrick. The swivel wrench (Fig. 85), which hangs from the traveling hoist running on the crane, is used for holding the tools in place when being screwed together.

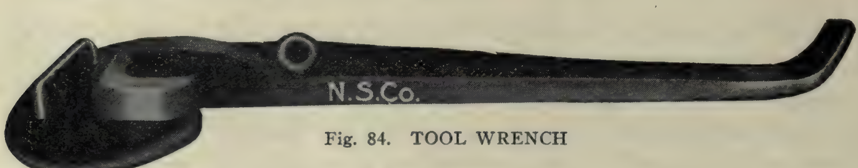


Fig. 84. TOOL WRENCH

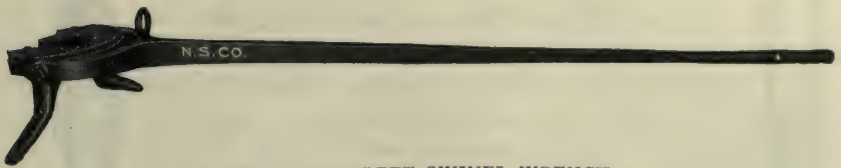


Fig. 85. BARRETT SWIVEL WRENCH

For removing drillings from the hole different designs of bailers are used, the working principle being the same in all, that is, a valve is placed at the bottom of a smaller size of pipe than the casing being drilled and a bail is riveted at the top. The valve opens when it strikes the mud or water and closes when the bailer is lifted from the well. In the flat-bottom bailer, a hinged valve upon a flat seat

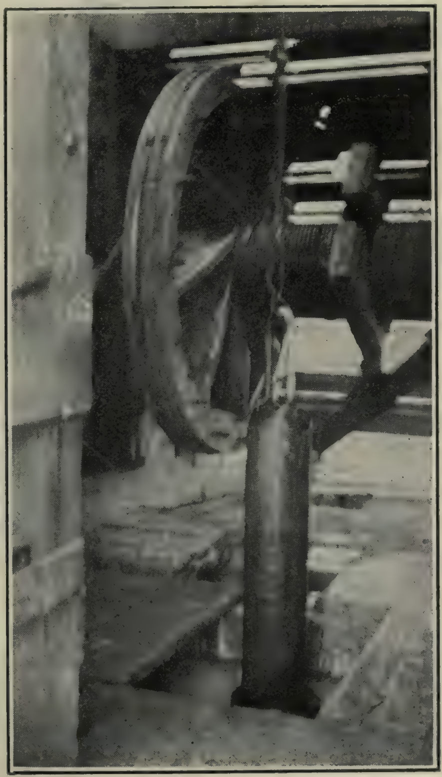


Fig. 86. BAILER ENTERING HOLE

is used, while in the dart-bailer (Fig. 87), a ball with a dart for a guide and a seat answers the purpose. In the Morahan (Fig. 88), or other special forms, suction is provided by means of a long plunger with a valve at the bottom to remove sand or broken particles of iron from the hole.

When the drilling-tools have been 'strung up,' the crown-block is moved if necessary to allow the bit to strike bottom in the same vertical line as the slot in the walking-beam for the reason that the latter supports the tools later on. As the stem and bit are over

Fig. 89. SPUDDING-SHOE

30 ft. long and extend above the beam, it will be seen that other means must be provided to deepen the well to a point where the temper-screw can be used. This method is called 'spudding-in' and is carried out as follows: The bull-rope is placed on the bull-wheel, the tools lowered to the cellar-bottom and enough slack run out from the bull-wheel to permit connection to the crank-shaft by a manila jerk-line. A spudding-shoe (Fig. 89), which is anchored by a bridle fastened to the back derrick-sill, is placed over the drilling-cable and a clevis passed through an eye in the jerk-line to the lugs of the spudding-shoe. The spudding ring is put on over the wrist-

Fig. 87. DART-BOTTOM BAILER

Fig. 88. MORAHAN SAND-PUMP AND BOTTOM SHOWING ENLARGED VIEW OF CHECK-VALVE

pin, which has been previously placed in the second hole of the crank-shaft and the outside eye of the jerk-line over the spudding-ring. All slack in the cable is then taken up by the engine until the tools are lifted from the bottom, when the bull-rope is thrown off and the engine allowed to run, raising and lowering the tools by the off-set in the crank-shaft. As the bit digs away, it can be kept striking at bottom by raising the bull-wheel brake and slacking the cable from time to time. Enough water should be used to thoroughly mix with the cavings, but too much water should be avoided as caving of the walls might result. Guides of wood are usually nailed around the stem at the floor to keep the stem dropping in a vertical line while the helper, or tool-dresser, turns it to avoid digging a flat hole. Turning the tools by hand usually continues until a depth of from 75 to 100 ft. has been attained, when the spring in the line will turn them without further aid.

When the hole becomes so muddy that the bit no longer drops freely, the bull-rope is put on, the spudding-shoe disconnected from the cable and the tools withdrawn above the hole and swung aside; the bailer is pulled from its resting place and lowered to bottom, where it is 'spudded,' that is, raised and lowered to bottom several times to pick up as much mud as possible. The bailer is then raised and its contents discharged into the dump-box. The operation is repeated until the drillings have been removed, when the tools are again run to bottom and spudding resumed. In drilling at any depth, it is always important to keep the hole as clean of drillings as possible to allow a free drop to the tools. In this way, 5 to 8 feet is made at a time. Should the walls begin caving at the surface, it is usual to place a wooden conductor in a well to a sufficient depth to exclude all cavings. When the stem is deep enough to be covered by the walls, the wrist-pin is placed in the third hole of the crank-shaft to permit of a longer stroke and a harder blow, and when a depth of from 130 to 150 ft. has been attained it is customary to substitute the walking-beam for the jerk-line. This is called 'hitching on'. The temper-screw is placed in the slot on the beam and a counterweight rigged back of the sampson-post to aid in pulling back the screw after it has been let out. The temper-screw (Fig. 91) consists of a 2-in. by 5 or 6-ft. screw with coarse, square threads which run through a box having wings at the lower end, where a split clamp held together by a set screw, is placed. A tee rests upon the nose of the beam, and two guides or reins run the length of the screw to the box. Attached to the

latter in notches at the top edge are the 1-in. links, by which the wire or manila line is suspended. The manila clamps (Fig. 92) are larger at the top than the bottom to permit of a wrapper of soft rope, usually about 5 ft. long, being applied to the cable on the line just above the clamps. When the bull-wheel brake is raised, the line pulls the wrapper tightly into the clamp, forming a

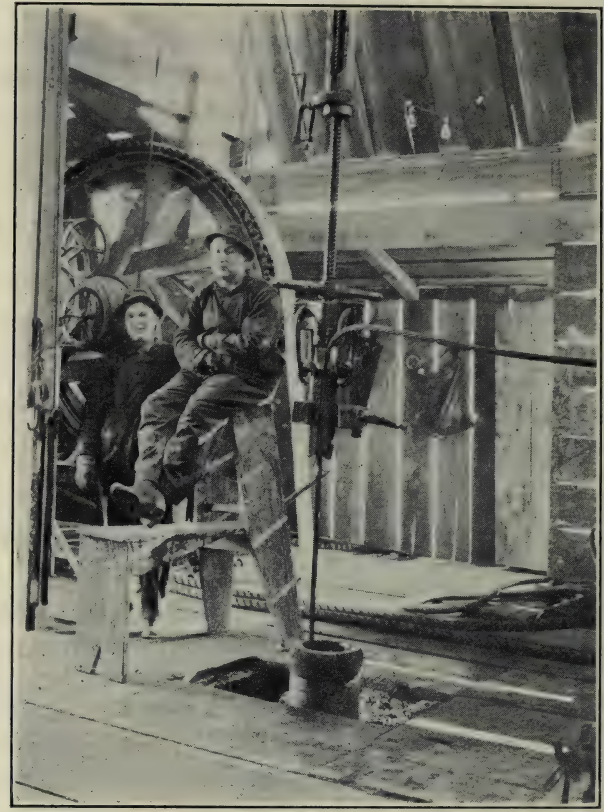


Fig. 90. DRILLING CREW 'AT WORK' WITH ELECTRICALLY OPERATED STANDARD DRILLING TOOLS

tight wedge with the latter. The wire-line clamps (Fig. 93) are composed of two straight pieces of steel with grooves running through the centres to fit the size of the line being used. In each case a heavy iron 'C' having a set screw is used to tighten the clamps.

When lowering the tools into the well, the driller does not run them to bottom at once but applies the bull-wheel brake at inter-

vals of a few feet when nearing the bottom in order to get the full stretch of the cable. In other words, the tools strike bottom on the spring of the line when drilling and the rebound is probably

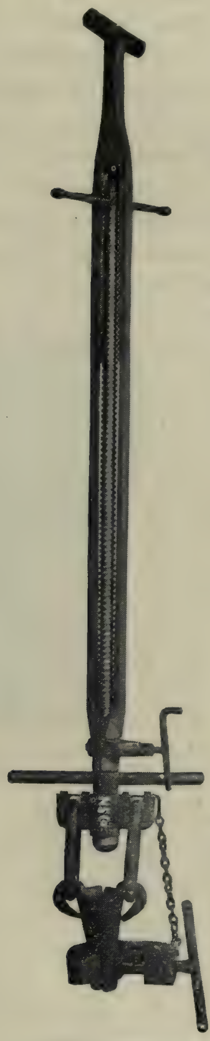


Fig. 91. LONG-FRAME TEMPER-SCREW WITH MANILA DRILLING CLAMPS ATTACHED

Fig. 92. MANILA-LINE CLAMPS

Fig. 93. SHRYOCK CLAMPS FOR WIRE ROPE

several feet. This action materially aids in mixing the cuttings with the water. In ordinary drilling, due to the spring in the line, the beam is returning on the up-stroke when the tools are striking,

creating a distinct jar on the rig, which grows more pronounced in a hard formation, especially when the wire-line is in use. Drilling usually proceeds in the open hole until the walls begin caving or until a sufficient depth has been obtained to insert the casing. Where stove-pipe is used, from 200 to 500 ft. is the ordinary depth, depending upon the method of lowering it. The stove-pipe used for casing in California is held together by dents made by picking, and care should be taken to avoid pulling the column apart. A depth of 200 ft. is ample when the string is being lowered without support, but some operators prefer putting it in on a smaller string of casing, in which case it rests upon a casing-spear or upon a cast-iron bushing attached to the bottom of the screw-pipe. The bushing has a left-hand thread and can be detached from the screw casing and left in the well where it is easily drilled up. Five hundred feet or more of stove-pipe can be lowered in the well in this way without injury. For lifting and handling this class of casing, wooden friction blocks 16 by 16 in. by 5 ft. are securely bolted around the pipe by four 1-in. bolts; a wire-line sling is placed on the casing hook and under each side of the friction blocks, so that the column can be moved by the calf-wheel. The stove-pipe in lengths of 10 or 20 ft. is coupled together by placing a drive-head on the top joint and dropping the tools on the column, by 'bull-roping,' that is, raising and lowering the tools on the drive-head (Fig. 94) by the bull-wheel. Should the coupling be too tight for bull-roping, the jerk-line and spudding-shoe are used as in spudding-in, and the casing driven together. The latter method is also used in driving or forcing the whole column of pipe when it does not follow or sink by its own weight. By placing the wrist-pin in the fifth hole of the crank-shaft to lengthen the stroke or drop of the stem, an unusually hard blow can be delivered. Hydraulic jacks are sometimes used to force the column down but are not as effective as driving with the stem. For this work, two 6 by 6 by 16-in. pieces of iron are securely bolted by 2½ by 14 in. bolts to the upper tool-wrench square shank of the stem. These are called drive-clamps (Fig. 95), and strike upon the drive-head, which sets inside of the casing upon the main column, at the same time projecting over and resting upon the top coupling or section. These heads, which are bored to admit passing over the stem, are used for all sizes of screw casing to protect the threads of the top coupling as well as for driving to loosen the casing should the latter become fast from cavings.

The cellar, when stove-pipe is being used, demonstrates its value, for a 20-ft. length can be inserted and drilled over without interfering with the operations of the temper-screw. Nearly all casing is inserted in the day by the combined crew, and when bottom has been reached, each driller and helper runs his shift or 'tower' of twelve hours.

In some localities, where the formation is solid, the stove-pipe is often held suspended on a friction-block, the walls of the well creating enough resistance to hold the string together. However, when a sufficient strain, by reason of the weight of the casing, has been attained to cause the joints to open, the pipe should be set on bottom. The reason for holding the casing up is to enable the bit to swing freely below the shoe, thereby cutting a larger hole than if the string

Fig. 94. DROP DRIVE-HEAD

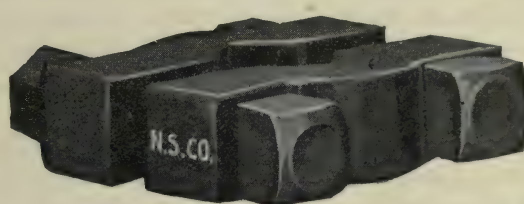


Fig. 95. DRIVE CLAMPS

were following. In drilling through any casing, it is always well, wherever possible, to keep the bit working from 15 to 30 ft. ahead of the shoe for this reason. Should it be found necessary to drive the stove-pipe, because of the caving mud or 'friction' behind it, clamping at the surface is not necessary. Stove-pipe is designed, primarily, to case out running sands, which would fall around the projecting couplings of a screw-casing and freeze or stick the string, but to reach the sands, beds of clay, shale, shells and boulders are nearly always encountered. As the clay is usually tough and resistant, the bit bores a small hole, leaving the stove-pipe shoe to cut its way through the walls, necessitating hard driving with the stem to force the string down. For this reason, many operators prefer the turnback starter-joint which has no shoe, as it follows the bit more readily by

reason of its smaller clearance. For drilling through blue clay, a short stem 8 to 10 ft. long, called a sinker-bar, is used above the jars to knock the tools loose when they stick or become fast, as often happens. The jars in such cases are loosened sufficiently to deliver a short, upward blow keeping the tools loose and saving considerable time which would otherwise be spent in 'switching.' This term is used to designate the high rate of speed at which the engine is run to jar the bit loose when no sinker-bar is carried. Short pieces of wire-line, when thrown into the well, are helpful in holding up the tools and enlarging the hole.

Gray or blue shale is usually easily drilled and ordinarily gives no trouble to stove-pipe, while hard strata of limestone, sandstone, etc., if carefully reamed with a sidehill bit and enlarged with small pieces of cast iron or short lengths of wire-line, should not interfere with the passage of the casing. Boulders are often troublesome, both to stove-pipe and screw-casing, particularly when small enough to roll behind the pipe and dent or mash it. Running sands are best handled by letting the stove-pipe follow through, or driving it ahead and bailing as little as possible. It will be found that the shoe of the stove-pipe is often several feet ahead of actual bottom until the sand stratum has been penetrated.

Aside from any fishing jobs that might occur from the use of stove-pipe, the principal troubles encountered are parting, collapsing, or freezing. Parting is caused by drilling out a sand plug or bridge near the bottom when the upper portion is frozen, suspending the whole column from the surface when the pipe may part from excessive weight, neglect of the driller to properly join the sections, tearing out an inside section with the bit when drilling, starting the walls to caving to such an extent that the in-rushing material forces the string apart, and driving the column together at some point. If the part comes near the surface, the hole can be continued by hand from the cellar down outside the column and the pipe properly connected. Should the part be deep, however, a swage can be run to bottom on a string of 6 or 8-in. screw-casing and slips or wedges lowered by the sand-line over the top of the swage when the smaller casing can be pulled, with the result that the swage pulls up against the slips and engages with the stove-pipe. A stem and fishing-jars are used above the swage and are coupled to the casing by a substitute connection, the latter having a mandrel at the top. When the stove-pipe cannot be loosened by an ordinary pull, a string of tools with a socket attached can be lowered inside the screw-casing and a hold taken on the mandrel. Jarring then proceeds, a strain being kept

on the inside string. Instead of using a second string of tools, the dead-line is often taken from the casing-block and attached to the back-sill of the derrick, the spudding-shoe and jerk-line are put on and an upward blow delivered by the inside column of casing to the stove-pipe. The latter, when freed, is withdrawn to the point where it parted and lowered again after repairs.

A swage can be used to remove dents made by boulders or to drive out collapsed portions. This work may be only of a temporary nature and should the pipe collapse a second time, as often happens, the swage again may be called into use and the pipe kept in fairly good condition until landed. In driving the shoe through a tight hole or tough stratum of clay, the shoe often becomes pinched or oblongated. In such a case the bit may be used to detach the lower portion and drive it to bottom where it can be drilled up—in fact 8 or 10 ft. is sometimes drilled off the bottom of a string a section or two at a time and disposed of in this way. When a string of stove-pipe cannot be forced by hard driving, it is usually abandoned and the next smaller size of casing run to bottom, for stove-pipe is much more difficult to handle than screw casing for the reason that it cannot be readily pulled back. One string is generally used in California, the average depth of landing in the deeper territory being about 750 ft. There are single 16-in. columns, however, over 1000 ft. long, the object being to shut out all sand-strata. The pipe is cut off flush after landing with the casing-sills in the cellar, in order not to interfere later on with the screw-pipe.

For convenience in handling all screw casing, a large iron ring called a 'spider' is placed at the cellar bottom. The spider has two projecting lugs for its support. The casing is run through a beveled hole and can be suspended at any depth by inserting four curved steel slips (Figs. 96 and 97) having serrated edges which act as wedges between the body of the spider and casing. The advantage of being able to lower the latter only a few inches at a time is often helpful in shutting out a caving formation, allowing the tools to work on bottom without interruption. Several makes of elevators are used, the Wilson (Fig. 100), Fair-Mannington (Fig. 98), Scott (Fig. 99), and Fisher being generally employed. The Wilson is easily manipulated, a door on the side opening wide enough to admit the casing instead of being hinged at the back as in the Fair, while the Fisher is especially reliable for extreme tension. With one exception elevators are made upon practically the same principle, that of two links by which the casing is raised, the body having a hinge at the side or back, to allow of its being placed around the casing. A

Fig. 96. SPIDER AND SLIPS

Fig. 97. LINER AND SLIPS FOR SPIDER USED FOR HANDLING SMALL SIZES OF PIPE

Fig. 98.
FAIR ELEVATOR

Fig. 99.
SCOTT ELEVATOR

Fig. 100.
WILSON ELEVATOR

device known as the latch holds the body together when in use. The Union single-link elevator (Fig. 101) possesses advantages in handling the larger sizes of casing. It has no hinge, but grasps the pipe by the insertion of two bushings (Fig. 102), after the body of the elevator has been lowered below the coupling.

The casing-shoe is placed upon a joint and tightened until it butts with the latter upon the shoulder, after which, hot babbitt is poured into the recess between the sleeve of the shoe and the pipe. This is done to prevent the shoe from unscrewing as well as to strengthen it. Casing is inserted one length after the other until

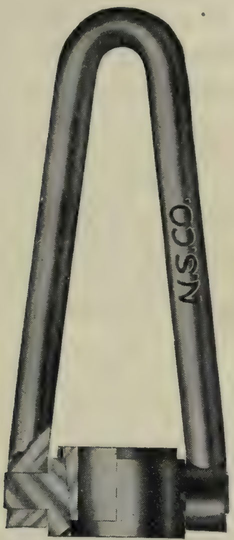


Fig. 101. SINGLE-LINK ELEVATOR

Fig. 102. BUSHING FOR SINGLE-LINK ELEVATOR

bottom is reached, care being taken to see that the threads are properly lubricated and the joints screwed straight. Each is started and screwed by hand after which a jerk-line is run to the crank-shaft, and the engine used to securely tighten the coupling, both at the 'mill' end and the 'well' end of the latter. Heavy pipe tongs are required for this work and are counterweighted at the swinging end so that no help is required to pull them back for a fresh hold. Casing 12½-in. diameter is generally used inside a string of 16-in. stove-pipe and is carried as far as possible, the average string in California being about 1500 ft. in deep-well drilling. After being landed, the 12½-in. casing can be cut off 50 or 60 ft. up inside the

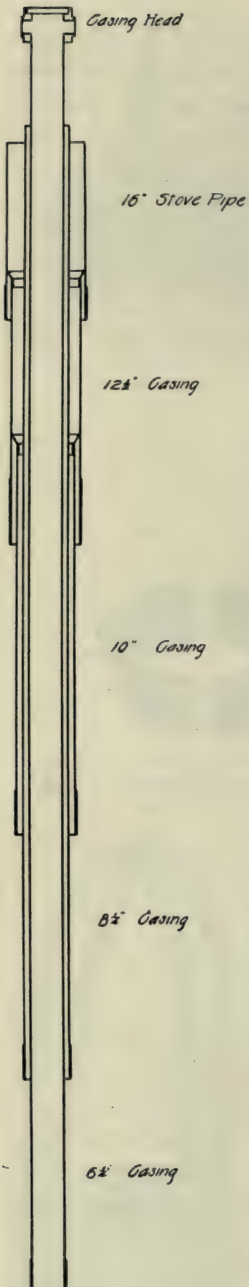


Fig. 103. RECOVERY OF PORTIONS OF THE 12½ AND 10-IN. STRINGS OF CASING

16-in. stove-pipe, effecting a saving in pipe. An adapter (Fig. 103), which acts as a guide for the 10-in. is placed upon the top of the cut portion of the 12½-in. to permit the smaller size pipe being lowered without danger of hanging up. If the 10-in., when landed, has not been used to shut out water, it can also be cut a few feet from the shoe of the 12½-in. The water-string, however, should extend to the surface, where it is suspended on landing-clamps which are placed under the top collar. A short string called a 'liner' can be used to run into the oil-sand, thus effecting a saving in pipe.

The blue shale in one locality may be firm and cause no trouble, while the blue shale in an adjoining district may cause considerable trouble because of its caving and unstable character. It is therefore impossible to foresee or to judge conditions until they are actually met, and for this reason no set rule obtains for the handling of pipe or the drilling of wells.

As before stated, the tools work more satisfactorily when 10 to 25 ft. below the shoe, the bit having more latitude for cutting a maximum hole. The casing should be kept low enough, however, to prevent the rope-socket from going below it, for should the drilling-line part, a difficult fishing job may be caused when the tools have a chance to lean against the wall of the hole instead of standing upright in the casing. When under-reaming, casing should be at least 5 or 6 ft. above where the under-reamer is working, to prevent its striking the shoe. It is not always necessary to under-ream shale, but the hole through clay and all hard formations should be enlarged to permit free passage of all debris which might otherwise wedge in between the collar and the wall and stick the casing. Where boulders occur, the use of the

under-reamer is advisable to pull them into the hole where they can be drilled up and a source of danger to the casing be eliminated. The formation in many oil fields is sharply inclined, and the tools must be held up or 'tight-hitched' to prevent following the dip of the strata and getting a crooked hole. To correct the latter, hard material such as cast iron, rock, etc., is thrown into the well and the hole plugged back to a vertical line, when drilling ahead is resumed. This often has to be repeated many times before a straight hole is obtained. Tight-hitching applies to practically all oil-well drilling, for there is liability of the hole going crooked at any time when the tools are allowed to run loose. Under the latter condition, there is also danger of twisting the drilling-line off, sticking the tools, or digging a flat hole when the bit is not free to turn. If the formation be caving, the casing should be alternately lowered and raised sufficiently often to insure its being entirely free. If the mud falls in against it, or, in oil fields phraseology, "The casing becomes logy," is should be pulled back far enough to free when the mud, which falls in, can be cleaned out. Brown shale usually makes good drilling and does not cave badly, while blue clay when once drilled usually gives no further trouble. Boulders may freeze or mash the casing. If not too severe, the dented portion may be swaged out, but if it be the water-string, the pipe should be withdrawn, the damaged portion removed and the string replaced. Water-sand is generally severe on screw-casing, and, in passing through it, freezing may be expected. In drilling sand out of the casing, the sand often packs so hard that there is some danger of splitting the joints, driving the bit through the pipe. Sand can often be held in check by dropping quantities of clay in the hole and mudding the walls, thus protecting the pipe from freezing as well as from the heaving sand.

When a string of pipe is frozen and cannot be moved by pulling, driving is usually resorted to. It should be remembered that ordinary casing is not intended for such usage because of the fact that the ends of the joints do not butt. In other words, the blow is delivered upon the threads themselves and for this reason driving should be avoided as far as is possible. After driving, the casing-tongs should be applied and the string tightened again. Water, when not present in the well can be run in, materially aiding in holding back the cavings from the pipe. In case of a frozen string, the water can be bailed down, the mud started around the shoe and the pipe thus relieved. Should these means fail, the shoe-joint is sometimes slitted or perforated and pump-pressure applied to try to obtain circulation

of the material behind the casing. This often proves effective and can be done cheaply. The use of a casing-spear for freeing pipe is not always advisable, for at best it is a dangerous tool, often 'bull-dogging' and sometimes plugging the hole. They are generally called into requisition as a last resort. In place of this dynamite is used to blow off the casing above the point of friction, and the top portion can be pulled out, a new shoe put on, and the pipe which is left in the hole side-tracked. Blasting, however, often does damage where none is intended, particularly to the water-string, if there be one in the well. The dynamite should be used in small quantities; 10 to 15 lbs. of a 40% strength of nitro-glycerine makes a fair charge for parting pipe. The casing-cutter often answers this purpose and eliminates the danger due to explosives, but the shock caused by the latter results in loosening the pipe more readily and is used oftener for this reason. Ripping the pipe will often free it, as the mud is then admitted to the hole and bailed out.

Side-tracking the casing left in the hole is not difficult when the formation is soft; the bit will probably strike the pipe at first, but by continued work will finally slide past. The reamer can then be run, if necessary, to clear the hole for the casing to follow, and when once it passes the top of the shot portion, an ordinary rate of drilling can be maintained. When shooting or cutting, enough pipe should be left in the hole to insure its remaining in a vertical position, making side-tracking much easier than would be the case in which only one length remained. It will usually be found that the casing is more easily kept free when protected on one side by the lost pipe, and that a second freezing is not so likely to occur. It frequently happens, however, that two or even three lost strings are left in one well and while harder to avoid, they do not interfere seriously with drilling operations. Considerable quantities of iron have to be drilled through in such work and often follow down the hole for several hundred feet. Such a task may take a period of several days or even a week, but this is generally cheaper than moving the rig and drilling a new well. As it is necessary for the casing to make a bend in passing lost pipe, there should be a space of at least from 60 to 75 ft. between the latter and the string previously landed, to permit an easy curve. Considerable pipe has to be drilled through when the two are closer, especially in the larger sizes, and occasionally it becomes necessary to abandon the well and move the rig away 20 ft. or more for a fresh start. In this case, pipe is either blasted or cut where it can be moved and used in the new well. The casing-splitter can also be used to part casing by driving it through a coupling once

or twice, after which the pipe can be pulled apart. Where the latter parts at a defective coupling, a die-nipple (Fig. 104) can be run in and new threads cut by turning the string at the surface. After a good hold is obtained, a pull may be exerted and the whole column withdrawn.

Water in large quantities is often encountered near the surface and stands within a hundred feet or more from the top; it usually gives no trouble in freezing pipe, maintaining its level when heavily bailed. Where the flow is small, the level should be kept constant by adding water when necessary in order to hold back the cavings and protect the casing. Where the source is deep and the flow strong, the hole should be previously filled to prevent freezing or collapsing the casing when the new stratum is encountered. A constant circulation of water from the inside is helpful in holding back the cavings of

Fig. 104. DIE-NIPPLE (MALE AND FEMALE)

water-sand and mud and when once begun should be continued until the string is landed. While cementing the water-string is now recognized as being the safest means of protection to the oil sand, many operators shut off the water by landing on a shell of limestone, sandstone, etc., or by driving the casing into a stiff bed of clay. In the former case, pipe is previously spudded as far as it will go into the shell and left to stand, when bailing follows to test for leakage. In making a landing in clay, a smaller bit is put on and 25 or 30 ft. drilled and the casing driven into the small hole after which the water is bailed. Additional clay is sometimes dumped into the well, thoroughly mixed and forced behind the casing by screwing a plug with a small valve into the top coupling of the latter after which it is raised, the valve closed, and the string lowered, forcing the clay behind the pipe. The clay gradually settles around the shoe, forming an impervious plug through which the water cannot penetrate.

For bailing water, the dart-bailer is used, usually 40 ft. in length for 6 and 8-in. casing, and a 2000-ft. hole can be bailed dry in 12 to 16 hours, occasional intermissions being taken to keep the sand-reel bearings from running hot.

In new territory where the character of the underlying strata is unknown, the standard-tool equipment is best for making tests of probable oil-bearing formation. Where a shell occurs over the stratum to be tried, the pipe can be landed temporarily upon it and the water bailed. Should there be a good showing of oil, the casing can be left permanently providing the water has been bailed out. When the showing is not sufficient, however, the casing can be loosened with a spear, blasting, cutting, etc., and carried on. In prospecting it is necessary at times to sacrifice a string of casing, good judgment being necessary to determine this. The drillers too should be especially reliable for this character of work, as a valuable deposit of oil may be overlooked in having the hole muddy or through lack of attention to changes of formation. A sand carrying a high-gravity oil may be so washed as to give the appearance of water-sand and it is often only by careful tests that the presence of oil is detected. In many oil fields the formation is so irregular that each oil-sand has to be tested separately for water, and while expensive, it is necessary, as the future success or failure of the property depends upon the initial tests made. The proper time for testing is when the measures are first penetrated. Later on, if water should make its appearance, its definite source cannot always be located except by long and tedious trial, pumping, bailing, etc. In going into a known source of oil, a high water-level is usually maintained to prevent the sand from heaving and sticking the drilling tools. When a sufficient depth into the sand has been obtained, bailing can proceed and the water be exhausted. Added knowledge of the strata, however, may be had by carrying no more water than is necessary to hold the sand down, for the presence of water in the sand is then more readily detected. Each sand in the well, if there be more than one, should be given a separate bailing, and where there is danger of encountering bottom-water, tests should be made at frequent intervals. After having reached the oil-sand, casing can then be released at the surface and often made to follow by bailing ahead instead of drilling with the tools; if it stops on a shell, a trial by pumping can be made to test the productivity of the sand before deepening. This character of work is often tedious, but its importance as a means of protecting the oil measures can hardly be over-estimated. A well should not always be judged by its first showing, for the initial gas pressure is

often heavy, subsiding in a few days, while other wells apparently 'dead' often become good producers.

If the casing has not been landed upon a shell, or in a body of shale or clay below the sand, a wooden plug having a wedge at the top should be lowered to bottom and the wedge driven by the tools to expand the plug to the diameter of the casing. After this an iron heaving-plug should be placed on top of the wooden plug to prevent the latter from being dislodged and coming up the hole. The iron heaving-plug (Fig. 105) has four slips which wedge to the side of the casing and keep it in place.

Rotary Method. The use of the rotary is becoming more general in all oil fields, particularly in California, where, until a few years

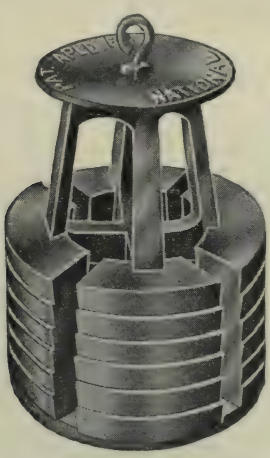


Fig. 105. NATIONAL HEAVING-PLUG

ago, it was considered by many operators a failure. Its recent success is due to improved tools and methods as well as having attracted a better class of drillers, until, at the present time, there is little territory in that State which cannot be successfully drilled with the rotary. While the number of men required (10 to 11) is greater than that for the standard tools and the equipment more expensive, yet the time and casing saved far more than offset any additional labor. The rotary was originally made by the American Well Works and used in North Carolina. The working parts were crude and it met with indifferent success. The first oil-well rotary was used at Corsicana, Texas, and became widely used in the Beaumont field at Spindle Top, Texas. Improvements in rotary machinery have

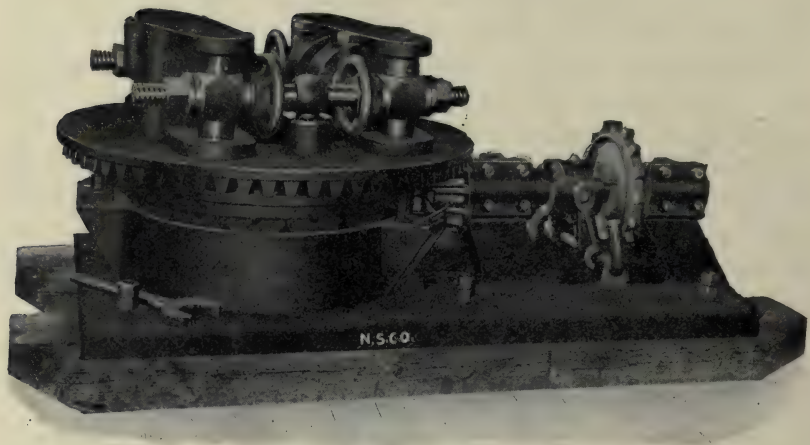


Fig. 106. NATIONAL ROTARY TABLE

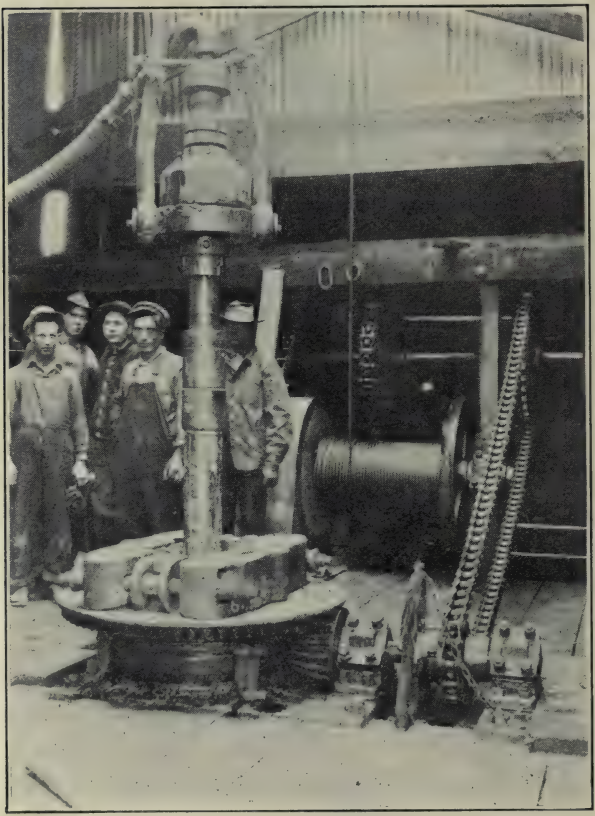


Fig. 107. ROTARY DRILLING RIG AND CREW

gradually been made until at the present time all the working parts are capable of meeting the severest conditions.

The practical operation consists in rapidly rotating a column of pipe, at the lower end of which is a cutting-bit, the pipe being lowered as drilling progresses and the drillings washed out by the action of a pump. The walls of the hole are 'mudded up' with clay to prevent caving, at the same time causing the pipe to turn more easily, while the mud can be used over again by running it back to

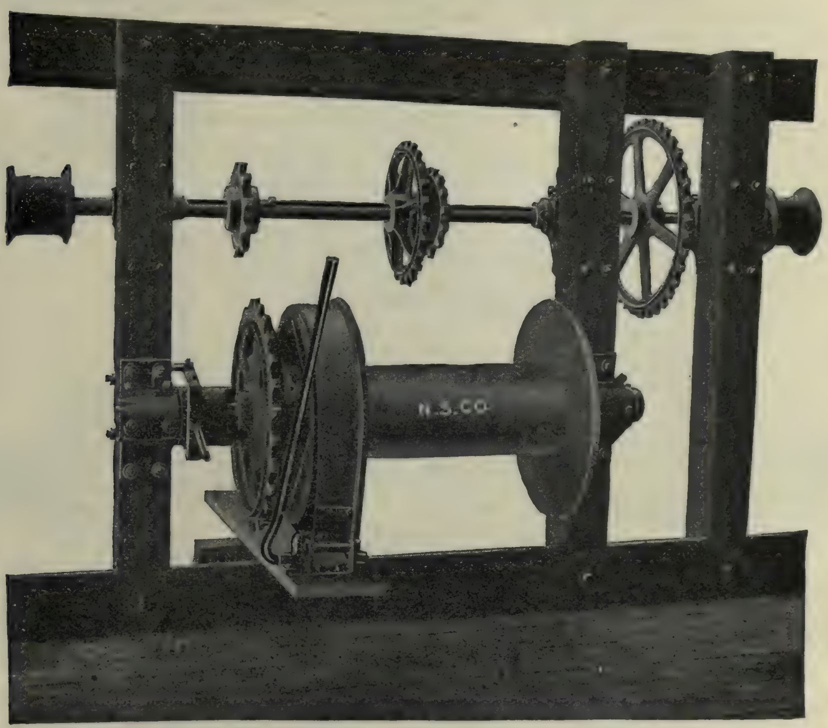


Fig. 108. LIGHT-WEIGHT DRAW WORKS

the pump-suction. The equipment consists of a turntable, draw-works and line-shaft, drill-stem, engine and boiler, two pumps, swivels and hose and the bits besides other special apparatus. A 12 by 12-in. engine is generally installed and transmits power to the line-shaft by sprockets and chains. On the line-shaft is a sprocket by which the draw-works (Figs. 108 and 110) are revolved, the larger pipes having sprockets for a low and high-speed gear. In line with the sprocket wheel on the rotary table is a larger sprocket

wheel on the line-shaft, while a chain furnishes the motive power. Two powerful brakes are placed on each side of the drum for control by the driller. The throttle-wheel brakes and clutch are so placed that each can be manipulated by the driller without moving. The turntable (Figs. 106 and 109), consisting of a heavy rotating device running upon steel rollers, controls the drill-stem by grip-rings which are set up sufficiently tight to turn the pipe without mashing it. A patented drill-stem is now in use which takes the place of the grip-rings. A special head sets in the open space of the table, and the drill-stem, which is 30 ft. long, can be run through it and at

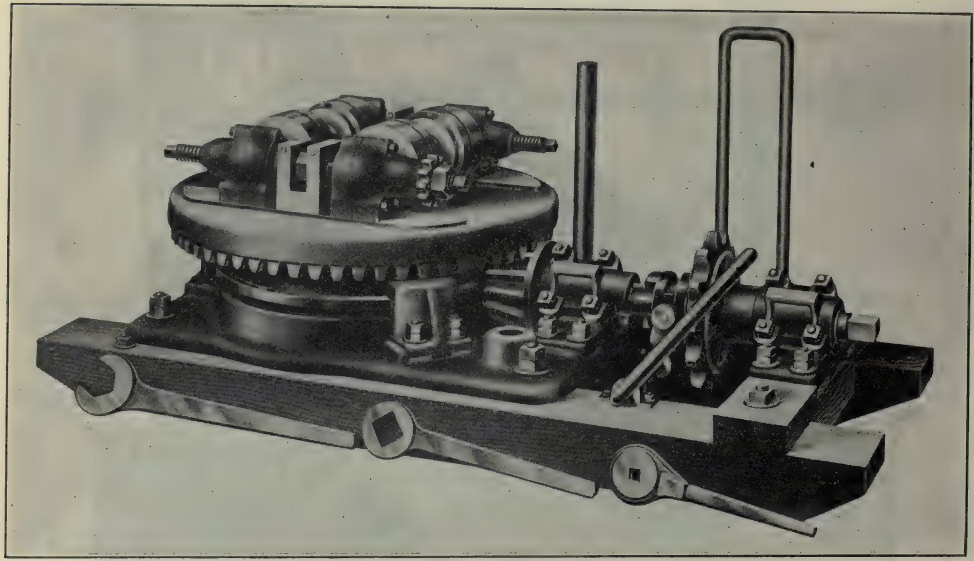


Fig. 109. IDEAL ROTARY TABLE

the same time rotated by wings which project from the stem into the head. This stem is never lowered below the table, a joint of pipe being installed below it each time instead, so that it always works through the rotary table. This effects a saving in pipe, grip-rings being unusually severe on the drill-stem. When pulling or lowering the latter into the hole, a spider is substituted for the special head and slips are used as in the standard-tool drilling. The pumps are 10 by 6 by 12-in. and are so connected as to run singly or doubly. Each is provided with a screen in the discharge-line to prevent packing or debris from the pit getting into the drill-stem

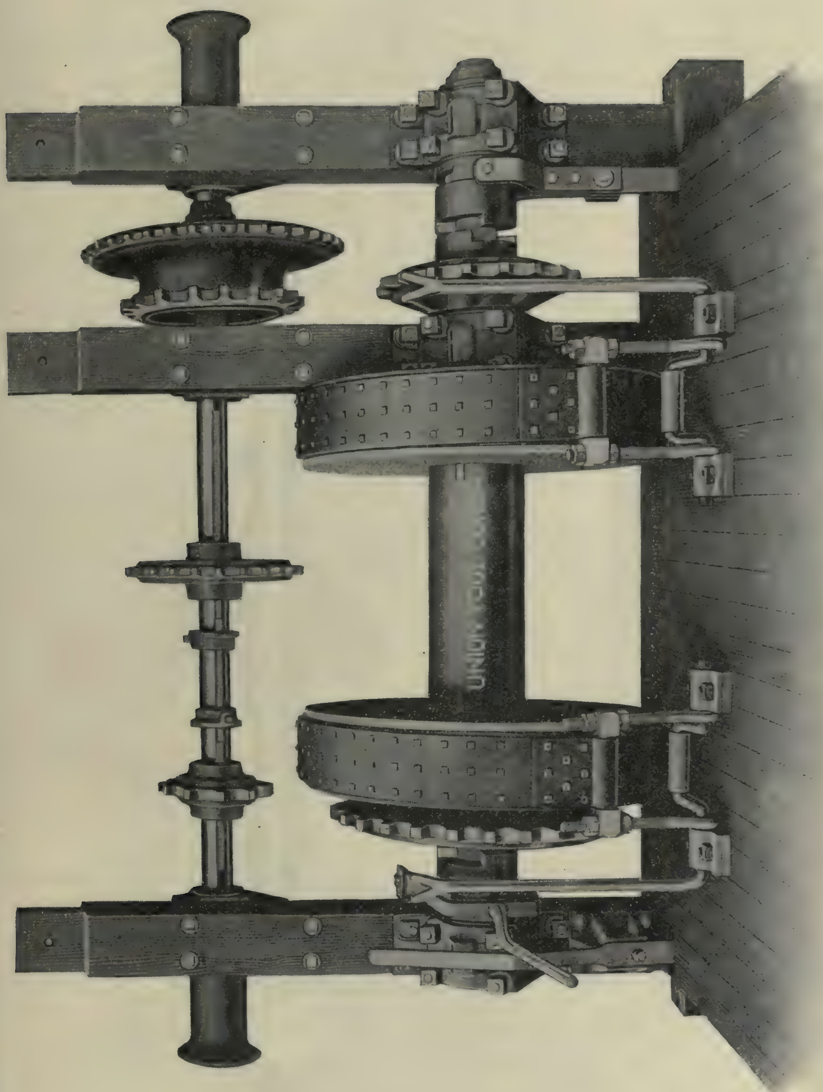


Fig. 110. IDEAL DRAW WORKS (HEAVY)

and plugging the bit. Connected with the discharge-line are two 30-ft. lengths of heavy wire-wound hose and when rotating, one is attached to the swivel (Figs. 111 and 112). The latter is screwed into the top coupling of the drill-stem and has a long bail or link by which the drill-stem can be raised or lowered. Roller bearings are used in the swivel to support the weight of the drill-stem at the same time allowing it to turn around without twisting the lines.

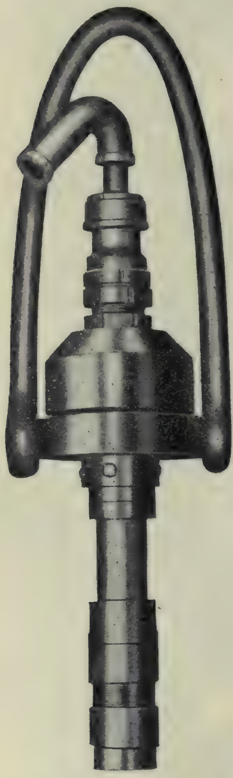


Fig. 111.
IDEAL HYDRAULIC SWIVEL

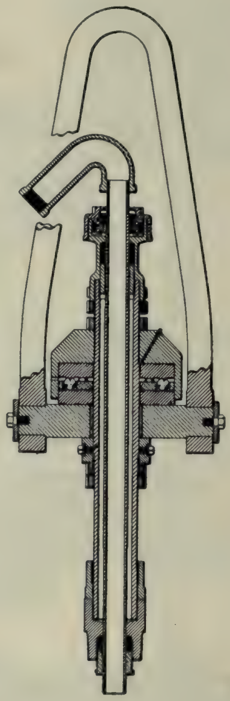


Fig. 112.
IDEAL HYDRAULIC SWIVEL

The mud coming from the well is conveyed by a box-ditch running from the outlet around the derrick to the slush pit, where it is again taken up by the pump suction. In some of the deeper fields, a hole 4 by 4 by 10 ft. is excavated under the derrick floor, a joint of 16-in. stove-pipe set into it vertically, and the outside space filled with concrete. This prevents the walls at the surface from caving and provides a good base for anchoring the casing. A heavy

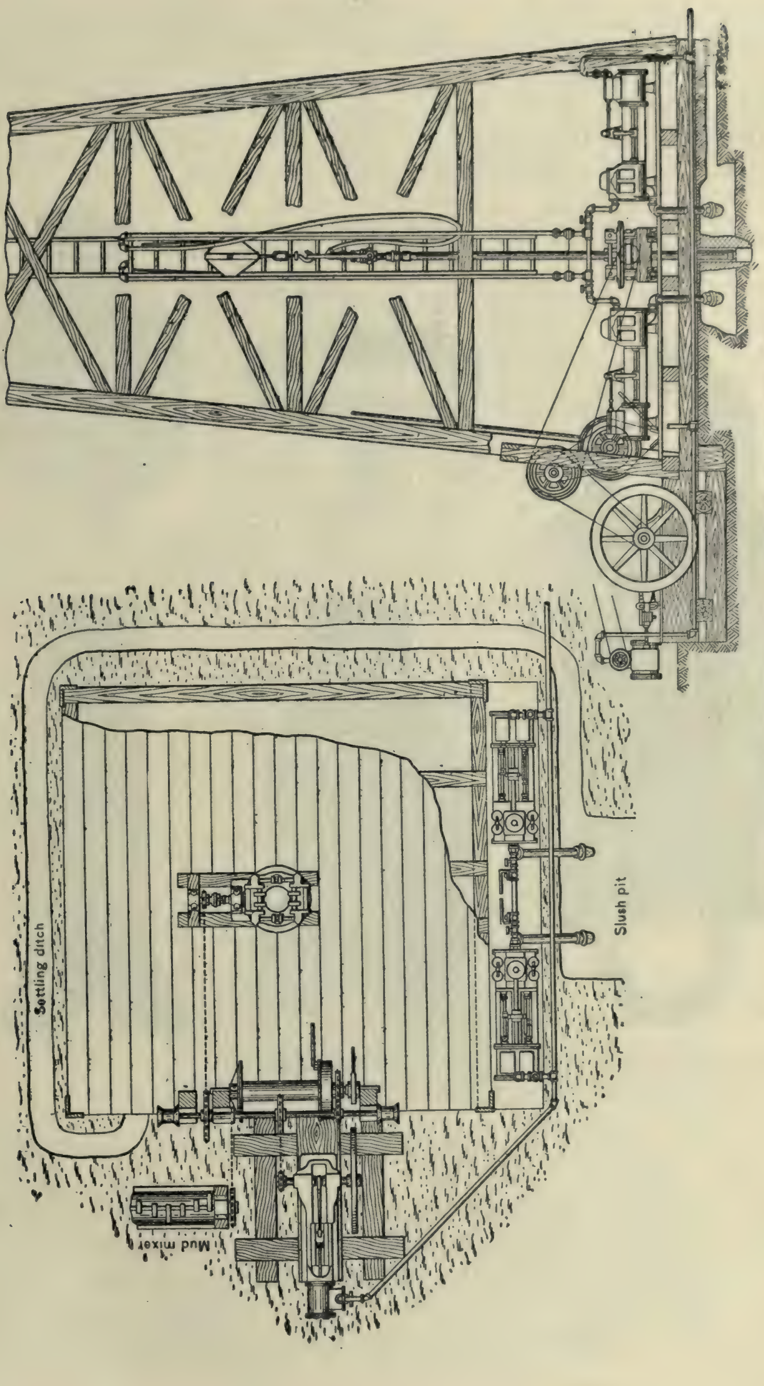


Fig. 113 GENERAL ARRANGEMENT OF ROTARY DRILLING RIG
(U. S. GEOLOGICAL SURVEY)

4-sheave block (Fig. 114) is used for handling both pipe and drill-stem tools, the larger sizes weighing 2700 lbs., while a 6-in. casing-hook is suspended from it by a heavy 'C' link (Fig. 115). Nine lines can be threaded on the deeper wells, five being the usual number at the surface. The fish-tail bit (Fig. 116) is commonly used, 14 to 15 in. being the usual sizes for starting the well. The ends are dressed

Fig. 114.
QUADRUPLE SNATCH BLOCK FOR WIRE ROPE

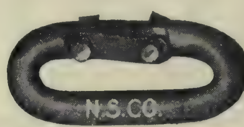


Fig. 115.
STRAPPED 'C' LINK

Fig. 116.
FISH-TAIL ROTARY BIT

Fig. 117. CHISEL OR DIAMOND-POINT BIT

Fig. 118. DRAG BIT

with a taper and turned back slightly to form a cutting-edge while the later types have a long shank which tends to ream the hole and keep it straight. Through each side is bored a ¾-in. hole, through which the water under pressure enters, strikes bottom and returns between the wall and drill-stem carrying with it the drillings. Other rotary bits for special uses are the chisel-point (Fig. 117) for drilling past pipe or drilling out wash-rings. The drag-bit (Fig. 118) is

similar to the regular fish-tail pattern, except that the cutting edges are reversed so that they drag. This form of bit is used in drilling through hard rock, adamantine being dropped into the well to make the cutting faster. The drag-shoe is also used in the same way, leaving a core to be extracted later. The core-barrel

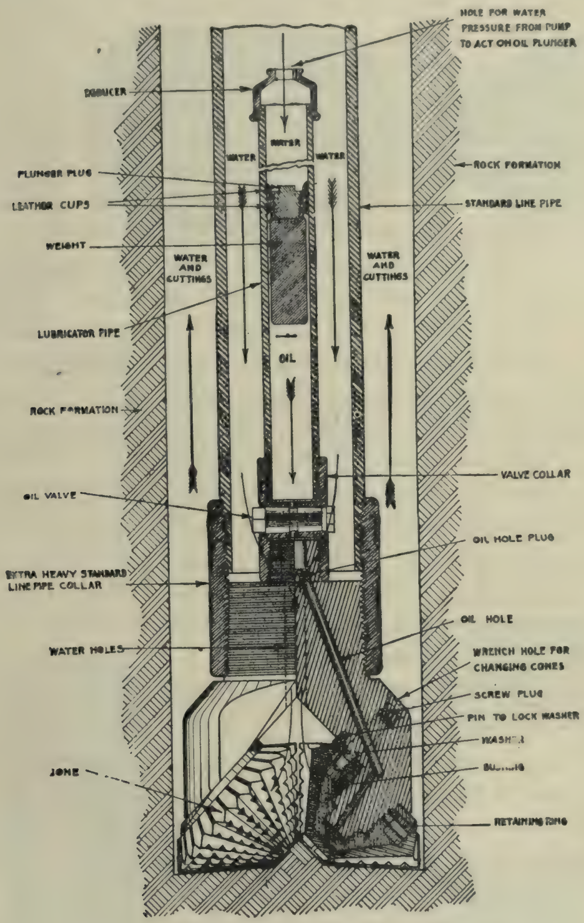


Fig. 119. SHARP & HUGHES ROTARY BIT

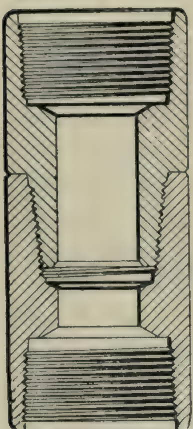
is also made to drill hard formations with about the same result as the drag-shoe, the core being removed in either case by throwing in small pieces of cast iron which wedge between the shoe or barrel and the core, when the latter can be broken off and extracted. Adamantine should be sparingly used and the couplings be kept free

from it, else the threads become badly damaged. When possible, adamantine does better work without circulation, as the water washes it away from the bottom. To extract more than 2 ft. of core at a time is dangerous, for breaking it off becomes a difficult matter, the drill-stem often parting in the attempt.

In California, a disc-bit has been invented which cuts through shells with greater rapidity than does the ordinary fish-tail bit. Two heavy arms extend from the body, and at the lower ends are two saucer-shaped steel discs which revolve on pins, a water connection in the bit providing for circulation. This bit is rotated on bottom, the discs turning and cutting at the same time. The Sharp and Hughes bit (Fig. 119), however, is practically the only rotary bit invented which will cut the hard limestone and sandstone shells as quickly as the same work could be done by the standard drilling-tools. In fact, this bit will cut hard rock at the rate of about 1 ft. per hour, which is fully as fast or faster than can be done with the cable tools. Its use is confined only to hard formations, but in these it excels any rotary cutting-tool yet made. Two heavy lugs are held together by a collar, and the cones of specially-made steel with 60 or more rows of cutting-teeth revolve on pins on the inside of each lug. The lubricator pipe, 12 ft. long, is filled with a special bit-oil which is forced down into the bit by the pressure of circulating water above the plunger. The lubricator, when filled, will carry a supply for 24 hours. The cones act as a milling tool, and upon being rapidly revolved, cut their way through the shell. For reaming the hole preparatory to inserting casing, a four-way bit with water connection is used to remove any projecting boulders or shells on the walls which might interfere with the passage of the casing.

For the larger size holes, a 6-in. drill-stem does the boring. Many operators prefer a heavy pipe, 28 lbs. per foot being the usual weight, while others use a 20-lb. upset pipe, the ends of the joints being heavily reinforced at the couplings for about 6 inches. This pipe, while light in weight, gives excellent service and the danger of twisting it off is not so great as with a heavier pipe, due to the fact that it is elastic enough to permit the bit turning over a projecting boulder instead of throwing a severe torsional strain upon the drill-stem. Tool joints (Fig. 120) are placed at every third or fourth joint, depending upon whether the drill-stem is pulled in three or four-length stands. The joints are tapered (Fig. 121) as in those of the standard drilling tools, with a hole through the centre to allow passage of the drilling water. A shoulder 1 in. wide holds the joints

together when once screwed up. These joints save considerable time when pulling or lowering the drill-stem, as they are easily coupled or loosened, while the wear on pipe joints and collars is



TOOL, BOX END TOOL, PIN END

Fig. 121.

Fig. 120. TOOL JOINT

eliminated. For drilling through 8 or 10-in. casing, a 4-in. drill-stem can be used while a 2½-in. drill-stem is run in a smaller sized hole.

The drill-collar (Figs. 122 and 123) into which the bit is screwed has a pipe connection at the upper end and a tool-joint connection at the lower end; these collars are often made of solid billets and

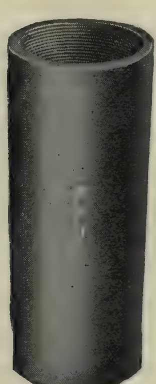


Fig. 122. DRILL COLLAR

Fig. 123. DRILL COLLAR

are 36 in. in length with 1½-in. stock. They are sometimes both babbitted and riveted to the lower joint of the drill-stem, making a stiff connection that is not readily twisted off.

On beginning to drill, the first joint of the drill-stem is plumbed and securely anchored in the derrick by braces until the hole is well started. When four or five joints have been added, the grip-ring attachment is laid aside and the patent drill-stem before described is substituted. The pumps are run fast enough to carry the drillings to the surface, at the same time keeping the hole clean. Where there is not enough clay present in the formation to 'mud up' the walls, this material can be hauled from a nearby well or bank, mixed and pumped into the hole until the caving ceases. The drill-stem is not forced, but a part of the weight is carried on a swivel to prevent a crooked hole and to 'mud up' the wall properly as well as to allow a free flow of water through the bit. Quite often the water does not return, by reason of the presence of a porous stratum, in which case enough clay is pumped into the well to get a complete circulation. This may take several days to accomplish, but it is necessary before drilling ahead can be resumed. When the bit becomes so dull that it does not readily cut the formation, the drill-stem is pulled and placed back in the derrick in 'stands.' Under severe conditions, where no other form of bit is procurable, it is necessary to substitute a fresh bit as often as every few inches, but under ordinary conditions, when drilling in blue clay or blue shale, one bit can be used for making from 50 to 100 feet.

The top formation usually is easily drilled, the average rate being 100 to 150 ft. a day. In most districts, however, boulders are encountered. They often can be forced into the walls and side-tracked, but when this fails, they must be ground up, withdrawn by a basket, or blasted. If the boulders are driven ahead until a shell is encountered a Sharp & Hughes bit can be used to grind them up, while often a charge of dynamite will save time by blasting them into the wall.

Sand of course is ideal for rotary drilling, the only precaution necessary being to watch the returns and see that the walls are 'mudded up.' Shales also drill easily, and clay, while sometimes slow, gives no particular trouble. Formations lying at an inclined angle should be drilled slowly, as with the standard tools, to prevent the hole from going crooked. The drilling-returns from a well furnish evidences of the formation being passed through, and the ditch should be closely watched for any changes. Experience is necessary to judge oil-sands, water-sands, etc., and in many instances where the character of strata is uncertain, the safest method is that of shutting out the water above the strata by cementing a string of

casing and later testing by bailing or pumping. Should the formation prove unproductive, the casing is lost, but this is a necessary additional expense where any uncertainty exists. Wells capable of making from 8000 to 10,000 barrels per day have later been discovered in territory where the returns from the sands had been misjudged. Gas makes its appearance known in the trench by froth or foam on the water, and this often indicates the presence of a sand. Some sands, however, show little gas, and for the additional reason that an oil-sand when washed, resembles a water-sand, it will be seen that the returns cannot be too carefully inspected.

Before putting in the casing, a four-way reamer-bit is run to bottom to insure its free passage. The drill-stem is then stood back in the derrick and the casing inserted as rapidly as possible so that circulation can be started again before the walls begin caving. Slide tongs (Fig. 124) are used to support the elevator on the rotary table when inserting or withdrawing pipe. When a hole cannot be circulated, the casing must be withdrawn to a point above the friction,

Fig. 124. SLIDE TONGS

and the pipe rotated back to bottom, where it is later cemented. In deep wells, where the weight of the casing is more than the draw-works can safely carry, calf-wheels are installed and the lines transferred to it. Another engine becomes necessary to move the calf-wheels, but when it is considered that the success of the well depends upon shutting out the water, this additional cost need not be considered. Ten-inch casing is usually set for the water-string, although 8¼ and 12½-in. are frequently used.

Heavy gas-pressures are generally encountered in the oil-sands or at some point not far above, and the rotary method is the ideal one for this character of work because the pressure can be overcome by heavy mud. When a heavy pressure becomes evident, the blowout-preventer is attached to the water-string, while a back pressure-valve is placed in the drill-stem at the bottom. The blowout-preventer is a heavy gate with four projecting clips which can be set up to the drill stem by means of a long handle operated outside of the derrick.

The clips fit snugly around the stem when closed, preventing the escape of gas or mud, while the body of the preventer has two screwed openings which communicate with the lead-line. This valve is also made to close when there is no drill-stem in the hole. The back pressure-valve screws into the pipe-couplings between joints, and is so arranged that a pressure below is resisted while the top-pressure can force it open. It often happens, in extreme pressures, that gas is not sufficiently checked and that there is danger of a blow-out. Heavy, clay mud can be admitted to the drill-stem by attaching a gate to the casing at the floor, while two or three joints extend above it to a second gate at the top. A hose is attached to the latter and the clay pumped into the column above the floor, when the upper gate is closed and the lower one opened, allowing the mud to slip down the hole. In this way the gas-pressure can be gradually checked until it gives no trouble. This method is called 'lubricating' and by its use the heaviest gas-pressures can be controlled.

Fig. 125. ROTARY SHOE

The greatest source of trouble when using a rotary is twisting off the drill-stem, that is, applying so great a torsional strain to the stem that the column twists in two. Frequently the relief from the strain or 'backlash,' as it is called, spins the stem in the reverse direction, often parting it a second time. Freezing the drill-stem does not often occur, but when it does, a larger string can be rotated over it to the bit, freeing it so that the whole column can be removed. When the entire drill-stem resists washing, pulling, etc., a larger string with left-hand threads in the couplings is run and a few joints unscrewed at a time by operating the rotary in the reverse direction until the hole is clear. It often happens that the casing is frozen while being run previous to landing. Where this happens, the same methods as in standard tools can be used. A rotary shoe (Fig. 125) is usually placed on the bottom of the first joint of casing.

While the rotary is not always reliable for prospecting, yet a driller with wide experience in judging the returns makes this method

nearly as safe as with the cable tools, especially where the drilling is done in daylight so that the ditch can be more carefully inspected. If the cementing-point is uncertain, a smaller rotary-bit should be used and when ready to set the casing, the hole can be enlarged to bottom in the usual way. After the oil-measures have been drilled through, the walls of the hole are left in the mudded condition until the liner is set into place. This is done by attaching the perforated pipe to the drill-stem by a left-hand coupling, which, when unscrewed, leaves an adapter or guide at the top, to prevent lodgment of the bailer, tools, etc., when cleaning out. In the southern fields, where the oil-sand is often a coarse gravel, a screen or strainer pipe is used, while in California, round or slotted perforations are generally considered to be better adapted to the fine sands usually found. When running the liner in, 2-in. tubing is used to carry the water to bottom instead of allowing it to return through the top perforations. The tubing is set upon a ring attached to the lower collar of the liner, and extends to the drill-stem, where it is attached to the latter with a bushing. The liner always extends 50 to 75 ft. up inside the larger string.

After being lowered to within a few inches of bottom, clear water is pumped into the well until the returns show only traces of mud. Then the liner is set on bottom and the drill stem detached from it. The latter is then pulled out and the well bailed and prepared for production.

Circulating System. When passing through running-sands or caving-shales with the standard tools, it often becomes necessary to 'mud up' the walls in the same way as is done with a rotary in order to keep the casing free and make progress. Two pumps are set on the derrick-floor with hose connections as in the rotary method, the flush-boxes and pit being also used. The swivel, however, is not necessary, as the casing is not turned or rotated but set upon the spider as in the cable-system. A circulating-head (Fig. 126) with 2-in. side-openings is screwed into the top-couplings of the casing and the hose connected to one of the openings. A long hollow-steel plunger is previously placed above the rope-socket and works through a stuffing-box in the top of the circulating-head. When drilling, the tools are lowered to bottom, the plunger raised with the wire line-clamps and there tightened with a set-screw, allowing space for the plunger to work without striking the circulator-head. Drilling is thus carried on simultaneously with the working of the pumps, the latter

carrying much of the cutting from the well in a form of sediment and depositing it in the trench where it can be removed. It is not necessary to bail as frequently as with the ordinary cable-system, 25 to 30 ft. often being made before the mud accumulates and prevents the free fall of the tools. Constant circulation of muddy water prevents the walls from caving, and keeps the casing free. The latter may be raised or lowered while pumping and a joint is added by removing the circulating-head whenever sufficient hole has been made.

After the territory becomes familiar to the operator it is often found that continuous circulation is not necessary. The pumps

Fig. 126. WILLARD CIRCULATING-HEAD OR OIL-SAVER

are run at intervals while the driller is absent for meals and the well shut down, while in other cases the well is circulated four or five times a day. If the pipe becomes 'logy,' pumping can be repeated at shorter intervals. Complete circulation is not always necessary, the important thing being to keep the walls of the hole completely 'mudded up.'

In using the combined rotary and cable-tool system, the bull-wheel and calf-wheels are installed, while on the right-hand side of the derrick are placed the line-shaft and draw-works with an extra engine. The pumps are placed on the left side and the

rotary, when not in use, can be removed from over the hole. It will be seen that one system can be changed to the other without much difficulty. For instance, if the cable-tools are in use and a change to the rotary is desired, the calf-line is transferred to the draw-works, the rotary table installed and, with a few minor changes, drilling progresses with the rotary.

In the Parsons and Barrett combination-method, provision is made for continuous drilling without any changes. A cellar 20 ft. deep is sunk and the rotary placed at bottom. The return-water is carried off through a tunnel at the level of the cellar-floor to a well, from whence it is drawn by a small pump and carried back to the pit. The casing is suspended by a bridle with two long, heavy wire-line reins which are fastened to the spider below and the casing hook above the walking-beam. These reins are wide enough to permit the beam running between them and are long enough to give sufficient freedom for lowering a length of casing without interfering with drilling operations. The rotary is applied direct to the casing and is run by a separate engine, while a special rotary shoe is attached to the casing. A circulating-head with plunger is used and the drilling is carried on at the same time that the casing is being rotated. The under-reamer or other cable tools can be used the same as in ordinary work. Some operators use the long reins without rotating the casing, thus eliminating the rotary table and extra engine. The casing can be moved at short intervals while drilling is being carried on.

CHAPTER V.

THE EXCLUSION OF WATER FROM OIL-SANDS.

Water, by reason of its greater specific gravity, displaces oil and gas. Therefore it is of first importance that the water seeping into the hole from water-bearing strata nearer the surface be prevented from flowing down the hole to the productive measures. Otherwise, when it has reached the latter it will displace the oil and gas, pushing them ahead of it, and eventually spread for a considerable distance throughout the measure. The readiness with which it travels laterally varies with such factors as the density of the oil, porosity of the sand, etc., but even with very heavy oils the entrance of water into the sand soon makes itself known, not only in the production from the well where it has broken in but also in that derived from the nearby wells. Thus it is that the carelessness of one operator may lead to the ruin of an entire district, even though all the other operators have exercised every effort to prevent the water from reaching the sand.

The importance of this subject is beginning to receive the attention it warrants, but not until much damage has been done in the older fields, where the encroachment of water is without question the most serious problem connected with the life of the wells. Many fields appear to have gone through the same stages. First the incipient appearance of water in the petroleum, then a gradual increase in the percentage of the water content, until finally the field becomes irretrievably flooded or else so far gone that corrective measures may be applied only at great expense. The difficulty connected with determining which well of a number in a zone is allowing the water to enter the oil measure, and the feeling of certainty expressed by each operator that it comes from another man's well, seem to point towards the imperative need for careful legislative action looking towards the effectual exclusion of the water at each well at the time it is being drilled and before the productive measures have been pierced, at a time when the thoroughness of the work may be satisfactorily tested. It seems too

much to hope that supervision will be provided for and wisely administered, but if this is not brought about, the prospects for a vigorous and continued life of the newer fields are slight. The presence of careless and incompetent operators, willing to take unwarranted chances in their efforts to hurry drilling operations, is inevitable in all fields, and in this situation the evil effects of their laxity are unfortunately not borne by themselves alone but also affect their neighbors.

All oil wells gradually decline in the amount of production, over periods of from a few months to several years. When water has made its appearance in a well the actual amount of moisture may be constant, but as the production of oil gradually falls off, the percentage of water will increase without there being an actual increase in the amount of water. Other wells act peculiarly in pumping all oil and then all water at intervals and such conditions are often hard to account for and equally difficult to remedy. However, when a well is pumping *some* oil it may safely be assumed that all the water is being cared for, provided the origin of the water is from that particular well, but when the well pumps nothing but water the case is of course hopeless unless the damage can be remedied. If the latter is found impossible, the entire hole should be plugged with cement to prevent the water spreading throughout the field.

The problem of water exclusion in its simplest form is merely that of inserting a string of water-tight casing, known as the 'water string,' so that its bottom is tightly lodged below the lowest water-bearing stratum and above the top of the productive measures (Fig. 127) thereby sealing it off from descent below the casing shoe. In the districts where the distance between the two strata is not small, this may be easily accomplished in most cases. But in some districts the water stratum may be separated from the oil by only a few feet, and here the mechanical difficulties and need for care are great if the water is to be properly shut off and the full value of the productive measure realized.

The lack of positive knowledge as to the positions of the top and bottom water strata gives rise to considerable doubt concerning where the water should be sealed off in any new field during the early days of its development, and the principal damage by flooding, aside from that due to negligence during subsequent operations, may be traced to this uncertainty when the first few wells were being drilled. It is the general opinion of oil men, experi-

enced in excluding water, that after the precise relative positions of these measures have been ascertained little excuse remains for not protecting the oil-sand. A number of methods for accomplishing this, under the various drilling conditions, have been devised and few situations arise that cannot be met if handled properly.

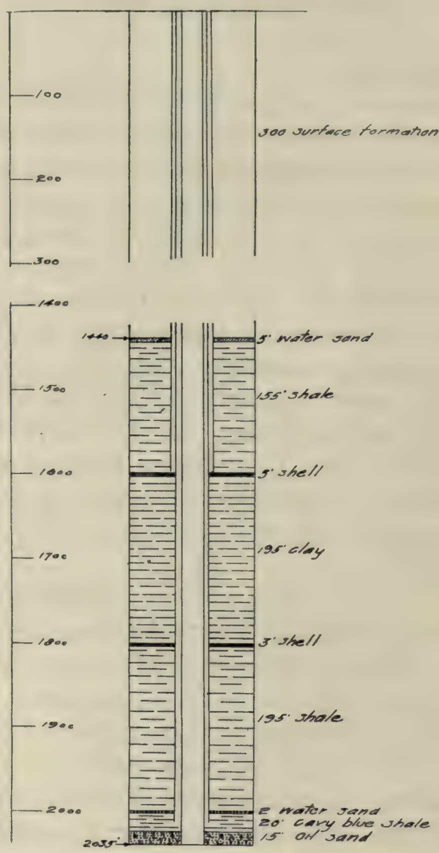


Fig. 127. LOG SHOWING WATER SHUT OFF BY LANDING CASING BELOW THE WATER-SAND

The original method used for shutting-off the water, which is still successfully followed in the eastern and middle western states where the strata are hard and cave but little, is simply that of setting the casing on bottom and proceeding with a smaller size drill, thus leaving a shoulder upon which the casing may rest and effect a water-tight bond with the wall of the hole. To be of permanent value, however, it has been found that this one-

time universal method is far from satisfactory in many cases, and particularly unreliable in soft, loosely cemented measures that may hold the water back for a few months and then permit it to break in by gradually leaching through the interstices of the surrounding porous measures.

In some such cases the proportion of water that works its way down to the productive measures is slight, and gives little trouble if it can be pumped out with the oil. But such instances are not the general rule, and it has become apparent that more positive methods for excluding the water must be applied if the lives of the wells are to be protected. In the first attempts at improvement, bags of cereals were inserted at the bottom, before the pipe was landed, so that a portion of these would expand on the outside of the casing and seal off the water. This did not prove very effective and the development of the use of cement followed as a natural consequence in the search for something that would hold back the water for all time. It has now been tried for several years, has come into increasing favor, and is generally recognized as by far the most satisfactory medium for permanently retaining the superficial water back of the casing.

The problem, then, is that of introducing from 2 to 8 or 10 tons of cement into the bottom of the well and placing it so that the major portion of it is situated on the outside of the casing at the bottom. The mechanical difficulties connected with accomplishing this are considerable in some cases; in others the actual work is simple and requires only care and experience. In all the processes to be described, the preliminary steps are the same and bear an important relation to the success of the work. The walls of the hole are under-reamed for from 75 to 100 ft. above bottom, in order that the column of cement may be as thick as possible, and the hole is washed by pumping in fresh water until all the mud, oil and gas have been removed. Both oil and gas tend to prevent the cement from setting properly and so interfere with the formation of a tight bond.

The simplest method of placing the cement is that known as 'bailing' it in. The hole is first filled with water and the casing raised until the shoe is about 60 ft. off bottom. A 'stand' of three joints of casing is then unscrewed and placed to one side in the derrick. The cement, mixed to a thick grout, is next run into the hole in a specially-constructed bailer that dumps when it reaches bottom. When 1 or 2 tons (dry weight) of cement have

been inserted in this way, the stand of casing is screwed back into the top of the string, filled with water, and a plug screwed into the top coupling. The casing is then lowered until the shoe strikes bottom, and since the pipe is full of water which is prevented from escaping by the plug at the top, a large portion of the cement at the bottom is forced out into the formation and up between the casing and the wall of the hole. The casing is then driven, in order to seat the shoe into the bottom as far as possible. Some operators prefer, instead of lowering the cement in a bailer, to run it in in a series of long narrow bags tied to the

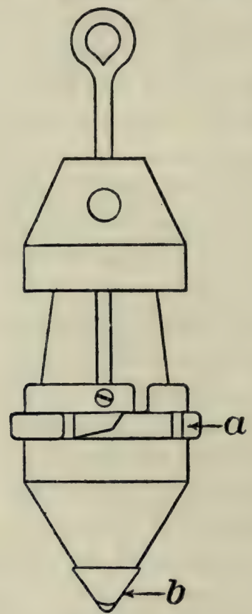


Fig. 128. BAKER CEMENT PLUG
a.—Slips. b.—Valve.

end of the drilling-tools. When the bottom is reached, a few strokes of the drilling tools loosen the bags and break them so that the cement is free to flow when the casing is lowered.

In connection with these methods the Baker 'cement plug' (Fig. 128) is sometimes used instead of the plug that is screwed into the top of the casing before it is lowered. The plug is made of light cast iron and so constructed that it may be hung from the bailer with a piece of soft rope and lowered inside the casing. When placed below the casing-shoe and then raised with a slight tension, a set of slips catch on the shoe and the bottom opening

of the casing is effectually closed. The casing is then lowered, the cement forced up on the outside, and the bailer loosened by a stronger pull that breaks the soft rope, leaving the plug in the hole. Being of cast iron, it is easily drilled up.

These methods, by which the cement is placed at the bottom of the hole and then worked out to its final position on the outside of the casing, have been largely replaced by processes in which the cement is pumped down, either through the casing or through an auxiliary smaller string of tubing lowered inside the casing for that purpose. With methods of this class, a necessary preliminary step is the securing of a 'circulation,' i.e., the space between the casing and the wall of the hole must be sufficiently cleared of caved materials so that there is a free passage for fluid pumped down inside the casing to come to the surface on the outside, thus insuring that when cement is pumped to the bottom it will pass readily around the casing-shoe and up on the outside of the pipe, if prevented from rising inside the pipe in cases when tubing is used. When endeavoring to secure a circulation it frequently becomes necessary to pull up the casing 100 ft. or more from bottom and resort to a pump pressure of several hundred pounds before the fluid will break through to the surface on the outside. The pipe is then gradually lowered, and worked up and down, until the fluid circulates readily when the shoe is only a few feet off bottom.

The type of pump ordinarily used is the 10 by 5 by 12-in. duplex mud-pump, used in the oil fields for pumping mud in wells being drilled by the rotary or circulator methods. It is connected to the top of the casing by a section of 2½ or 3-in. pressure armored-hose.

In the Perkins method, which is of particular value in very deep wells or those in which the water-string of casing tends to 'freeze' unless moved at frequent intervals, the cement is pumped directly inside the casing to the bottom. It is also known as the disc, or packer method from the fact that the cement is inserted between two moving packers that have an outside diameter almost as great as the inside diameter of the casing. After a circulation has been obtained, the casing is suspended so that the shoe is 2 or 3 ft. from the bottom, and enough fresh water is pumped in to clean the bottom thoroughly. The two packers have been prepared, one about 3 ft. in length, and the other of such length that when its lower end reaches the bottom of the hole, the upper end still remains in the casing. They are made of either wood

or cast iron, with ends consisting of heavy canvas or rubber washers of just the proper size to pass down inside the casing. The casing is filled with water, the shorter packer inserted in it and against this is pumped the cement, mixed to a grout just thin enough to be pumped readily. When the contents of the cement box is all pumped in, the longer packer is placed in the casing above the column of cement, and water is next pumped in, pushing the combination of lower packer, cement and upper packer down inside the pipe. When the lower packer has passed the casing shoe it falls to the bottom of the hole, permitting the cement to pass around the shoe and up on the outside of the casing, as it is pushed from the inside of the pipe ahead of the upper packer. When the latter has reached bottom it cannot leave the casing entirely, because of its length; it therefore stops the further flow of water and retards the pump, thus indicating that the cement is out of the pipe.

The casing is then landed on bottom, the cement has been placed on the outside of the pipe at the bottom of the hole and the packers, like the cement plug, are easily drilled through after the cement has set. The main objections to this method are the danger of the packers sticking while going down inside the casing, and the fact that the lower packer may fall to the bottom in such a way as to prevent the casing shoe from being landed squarely on bottom, getting underneath the shoe in such a position as to result in the cement bond breaking when the packer is drilled.

It is possible to follow the general lines of the above method, and dispense with the traveling packers by having previously measured into a tank, connected to the pump, the exact amount of water necessary to fill the bore of the casing from the surface to the bottom. The cement is pushed ahead of the water and is known to have passed out of the casing when the tank is drained.

In other methods a string of tubing is used as a conductor for carrying the cement to the bottom of the hole, whence it is made to pass to the outside of the casing. Probably the earliest of these was the 'bottom packer' method. In this there is attached to the lower end of the tubing a packer similar to the type described in connection with pumping-wells (Fig. 140), or a more simple one made from strips of belting confined between two metal plates (Fig. 129). The duty of the packer is to close off the space between the exterior of the tubing and the interior of the casing, leaving no room for the cement, when it is pumped down inside the tubing, except to pass around the casing shoe and up on the outside of the casing.

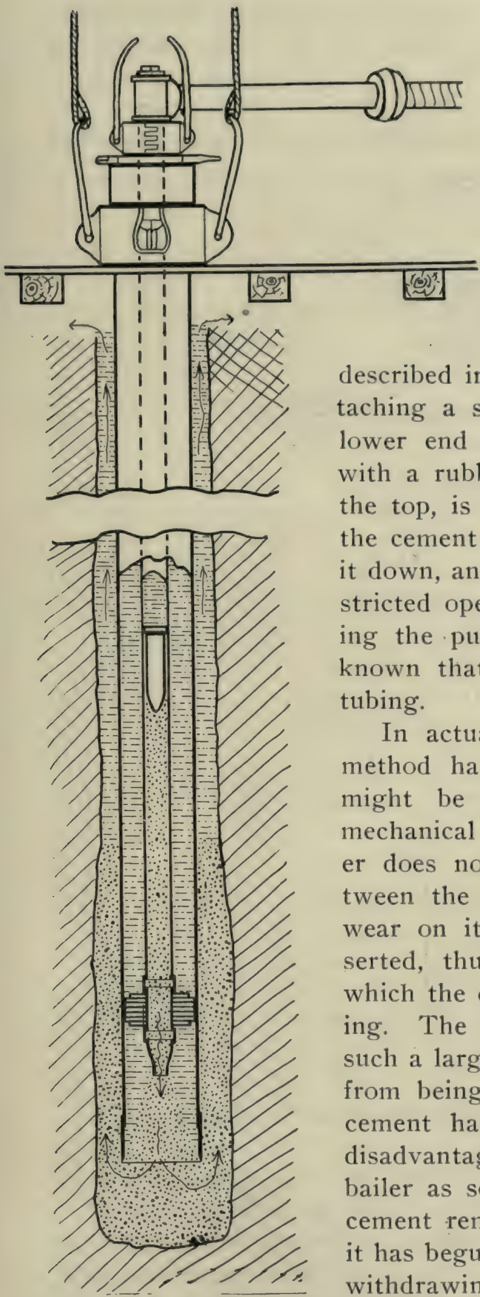


Fig. 129. CEMENTING BY THE "BOTTOM-PACKER" METHOD

In all tubing methods it is necessary that the precise instant at which pumping should cease be known, lest the cement be forced up a considerable distance on the outside of the casing. Provision for this may be made by previously measuring into a tank the necessary amount of water to fill the tubing, as described in the Perkins method, or by attaching a swage-nipple or bushing to the lower end of the tubing. A wood plug, with a rubber or canvas washer nailed to the top, is inserted in the tubing between the cement and the water used for forcing it down, and when the plug reaches the restricted opening at the bottom of the tubing the pump-pressure goes up and it is known that the cement is all out of the tubing.

In actual practice the 'bottom packer' method has not proved as successful as might be expected, because of various mechanical obstacles. Frequently the packer does not completely fill the space between the tubing and casing, due to the wear on its outside edge while being inserted, thus leaving an opening through which the cement works up inside the casing. The fact that the packer occupies such a large space also prevents the tubing from being rapidly withdrawn after the cement has been inserted, and this is a disadvantage since it is well to run the bailer as soon as possible and remove the cement remaining inside the casing before it has begun to set. The suction caused by withdrawing the packer tends to draw in cement from the outside of the casing, if the shoe is not landed squarely on bottom.

The methods now generally favored are various forms of the following typical example. Assume that the 8-in. casing has been carried to 2000 ft., where it is to be cemented, and a good landing place in the form of a hard shell or hard shale is the measure at the bottom of the hole. The 8-in. casing is suspended

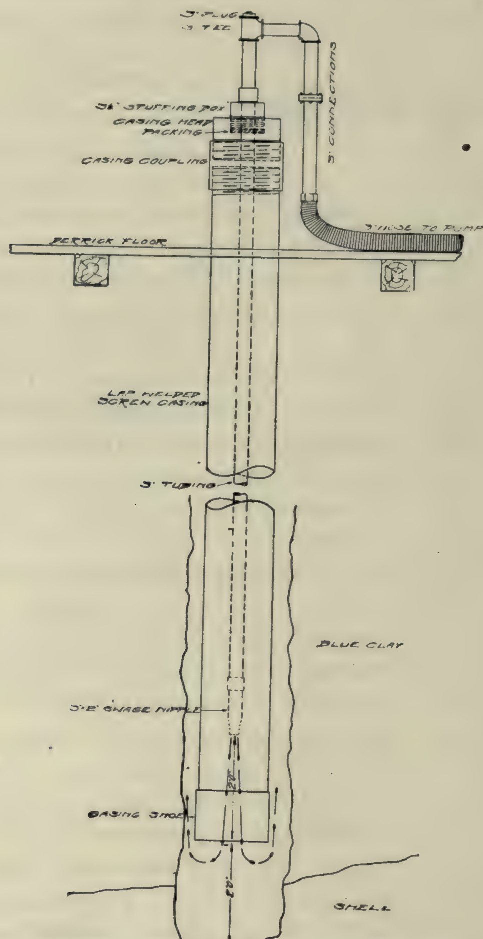


Fig. 130. "TOP-PACKER" METHOD FOR INSERTING CEMENT

from 2 to 6 or 7 ft. above the bottom and 3-in. tubing is run in to within 2 or 3 ft. of the casing shoe. A packing head (see Fig. 130) is stripped over the top joint of tubing and screwed into the top casing-coupling, packing off the space between the casing and the tubing so that if the casing is filled with water, when the cement is pumped in through the tubing it will be prevented from

rising inside the casing and must travel around the shoe and up on the outside. Fig. 131 shows the arrangement of the cement pump, mixing box, tanks, etc. The mixing box is 7 by 12 by 2 ft. and holds 8 tons of cement. The large tank, with a capacity of 100 barrels is used for water storage and the small tank as a receiving tank for the cement after it has been mixed in the mixing-box. A screen is placed over the top of the small tank to prevent lumps of cement or debris from entering the suction of the pump. The discharge-line, including a section of armored hose, connects the pump with the tubing.

When the tubing has been inserted, the packing head is screwed into the top casing-coupling and the tubing connected

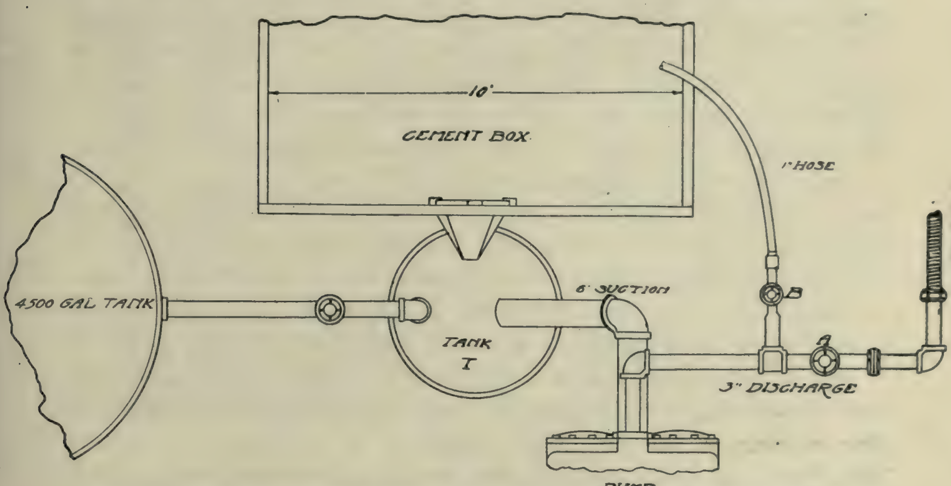


Fig. 131. PLAN SHOWING SURFACE ARRANGEMENT OF APPARATUS USED FOR CEMENTING OFF WATER

to the pump discharge, and fresh water pumped in again to make sure that there is a satisfactory circulation. The cement, which has previously been passed through a ½-in. screen into the mixing box, is next mixed with water by opening the valve *B*, leaving the valve *A* still open slightly so as to maintain a circulation in the well. Connected to the valve *B* is a section of hose with a ¼-in. nozzle that is directed against the cement for mixing it. At the same time, six or eight men stir the cement with hoes and the batch, say 5 tons, becomes thoroughly mixed in from 10 to 15 minutes.

The mixed cement is then run into the small tank *T*, from which it is taken by the pump and forced down the tubing. This

accomplished, the plug in the end of the tee at the top of the tubing is removed and a wood plug, from 1 to 3 ft. long, tapered at the lower end and with a canvas washer nailed to its top, is dropped into the tubing. The tubing-plug is replaced and water pumped in, forcing the wood plug and cement ahead of it down until the plug strikes the swage nipple, when a pressure on a gauge at the pump immediately goes up, indicating that the cement is all out of the tubing. The 8-in. casing is then landed on bottom, the tubing withdrawn and the bailer run in to remove the cement that remains inside the casing. At least seven days are allowed for the cement to set. The hole is then drilled about 10 ft. ahead of the shoe and bailed dry for the purpose of testing the cementing job. If at the end of a period of from 24 to 48 hours no water enters the hole drilling operations are continued.

When the well is bailed dry the greatest collapsing strain is placed on the casing, since no fluid remains inside the pipe to balance the pressure of that on the outside. The table on page 86 indicates the lengths of the different sizes and weights of casing that may be inserted, with an allowable factor of safety of 2; and while the limits set forth in this table are frequently exceeded, yet there is always the danger when doing so of subjecting the pipe to greater collapsing strain than it can bear, especially if it has been weakened by wear or by corrosion and pitting due to the presence of salts in the waters.

Before the tubing has been run in, during the preliminary operation of securing a circulation, the fluid may come to the surface on the outside of the pipe even though it is not traveling around the shoe, if a leak exists in the casing. If such is the case it may be determined by continuing to pump and at the same time lowering the casing until the shoe strikes bottom. If the casing leaks, the circulation will continue; but if no leak exists and the circulation has been entirely around the shoe, then when the latter is placed on bottom the fluid will be held and the pump-pressure increased until it stops the pump.

From 2 to 8 tons (dry weight) of cement is the amount customarily used, although greater quantities are inserted when unusually large cavities are to be filled. Preferences for different brands are found in different districts but there appears to be little advantage in any one make, provided the cement contains enough gypsum to retard the set so that the time of initial set is long enough to cover the period of mixing, pumping and landing the pipe. Ordinarily, when everything is running smoothly,

this occupies about a half hour. Since what is desired is a tight bond, rather than strength, no sand is mixed with the cement.

It sometimes happens, particularly with the early wells drilled in a new field, that after the productive sands have been drilled and the well is carried still deeper the so-called 'bottom' water is encountered, in water-bearing strata situated below the oil-sands (Fig. 132). The exclusion of such water is liable to be more difficult than that of the top water because of the presence of gas and oil in the hole, especially when the lower water occurs

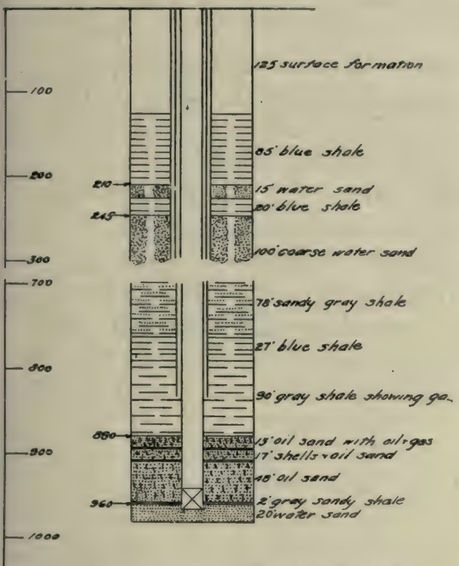


Fig. 132. LOG SHOWING WATER-SAND 2 FT. BELOW OIL-SAND

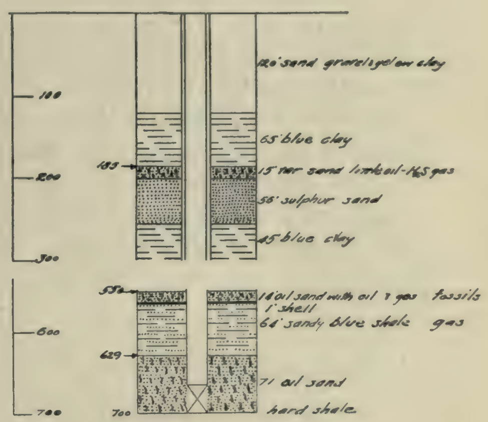


Fig. 133. LOG OF WELL IN WHICH WATER WAS FOUND BELOW A 71-FT. OIL-SAND

only a few feet below the oil-sand. Particular care must be exercised, under such conditions, in gauging the amount of cement injected, so that its level does not rise to the oil-sand and interfere with the production from the latter. If a streak of hard ground is between the two measures it may be possible to drive pieces of stone and brick, with a few sacks of cement, into this space and form a plug that will prevent the water from rising.

If a distance of 2 ft. or more intervene between the oil-sand and the water-bearing strata (Fig. 133) a 'bridge' may be formed in the hole above the water measure by driving down tightly bricks, stones, etc. These tend to hold back the water temporarily and provide a landing place for a body of cement, which is

pumped in through a string of tubing, run in until it is a few feet above the bridge. A similar bridge is also used when after the oil-sand has been penetrated and the well is finished, it is found that the water has broken in around the casing-shoe of the water-string. In such a case it is necessary, if the water-string can be loosened, to pull it a short distance up the hole and build a bridge a few feet below its old landing place, thus providing an artificial bottom for the hole while cementing the water-string by some of the methods described. In this way the bridge prevents the entrance of the cement into the productive measure.

In other instances, however, it is found to be impossible to loosen or move the entire water-string and either the next smaller size pipe must be inserted and cemented where the bridge is formed, or else the original string is cut off at a point where it can be moved and the hole re-drilled from this point off at the side of the original hole. Should the latter alternative be followed, the bottom of the old water-string should be filled with cement above the bridge prior to cutting it so that there will be no subsequent infiltration of water to the oil-sand through this old hole.

CHAPTER VI.

PRODUCTION.

Flowing Wells. Flowing wells are encountered in nearly every oil field of importance and are often of such violence as completely to destroy the rig and damage the casing in the well. The gas pressure throws the sand out with a force so great that it often cuts through heavy steel plates in a few hours, while the rig timbers fall rapidly before the blast. Such wells as the Dos Bocas in Mexico, the Lucas at Spindle Top, the Lake View in California, and the great Baku gusher in Russia produced thousands of tons of oil and sand before they ceased flowing, the first tearing a great hole in the surface of the ground before it subsided. Where a heavy flow is unexpected, and no preparations for capping have been made, to gain control is exceedingly difficult, often impossible. When a stream of oil is shooting into the air, there is naturally a heavy loss, especially of the lighter oils. To prevent this, boiler shells placed upon skids, or heavy timbers reinforced with steel plates on exposed surfaces are drawn over the hole at the derrick floor and prevented from being thrown off by wire slings anchored to the derrick sills. The oil is caught in earthen sumps excavated near the derrick, and, when the flow has abated somewhat, efforts are usually made to get the well under control. The Lake View gusher was controlled by placing a levee around the derrick 12 to 15 ft. higher than the mouth of the well. The oil, accumulating inside the embankment, acted as a cushion and prevented the flow from shooting into the air (Fig. 134).

Most operators do not believe in checking the flow entirely, for this might result in choking the underground oil-channels, thus ruining the well, the idea being, rather, to attach a heavy gate or blow-out preventer to the top column of the oil-string with a tee above the gate, if one be used, and the oil conveyed through a lead-line to proper storage. Extensions of all turns in the lead-line should be made with a nipple and cap to allow the oil to cushion, thus saving the fittings from cutting out by sand.

Should the flow be expected, the gate or other safety appliance may be installed in advance of the time of bringing in the well, when considerable loss of oil can be avoided. The pressure is

Fig. 134. LAKE VIEW GUSHER AT THE LAST STAGES OF ITS ACTIVITY

often so great, however, that the heaviest fittings do not stand (Fig. 135). In this case the well is temporarily capped with timbers or a steel shell until such time as it can be properly controlled. It is usual, in high-pressure districts, to fill in around the outer casing with concrete to a depth of 15 or 20 ft. and

Fig. 135. DAMAGE DUE TO HEAVY FLOW OF GAS, OIL AND SAND

securely anchor the strings of casing to the concrete block and to each other by means of casing-clamps and bolts, thus preventing any damage to the casing. Wells maintaining pressure as

high as 1000 lbs. are safely handled in this way. Although running the oil into earthen sumps causes considerable loss through seepage and evaporation, it is not always possible to do otherwise until the flow has abated. A large percentage of the oil from gushers is generally lost in this way, particularly so if the oil is of a high gravity. When the flow is going above the derrick, it is often possible to place heavy timbers across the second or third girts from the floor, which act as buffers and prevent loss. Occasionally a flowing well takes fire, and when

Fig. 136. BURNING TANK OF OIL
AFTER BURNING TWO HOURS — AFTER BURNING EIGHT HOURS
Upper Courses of Tank White-Hot

the well is not capped it is often a difficult matter to extinguish the blaze. If a sufficient number of boilers is available nearby, the use of steam is often successful in snuffing out the fire. Chemicals such as sodium bicarbonate and sulphuric acid are also successful at times if used in large quantities. Another method is to tunnel 8 or 10 ft. under the surface to the casing at which point it can be dynamited or squeezed together with jacks. The oil in this case runs out through the tunnel, lessening the flow on top, so that the flame can be extinguished by an application of steam. Danger from fire cannot be overestimated, for fire means

loss of property and often of life before being extinguished. Every precaution should be taken to guard against fire around oil-well derricks and tanks (Fig. 136). When a well is flowing and not under control, the neighboring boilers should be shut down and spectators kept at a safe distance. It is a good idea to completely fence the gusher and to install the boilers at a safe distance and at a point where the wind does not usually pass the derrick first.

Intermittent Flowing Wells. Where the oil and gas-pressure has diminished on steadily-flowing wells, they often flow for some time at intervals, maintaining a steady production. Many wells in the older fields start their initial production in this way. Enough oil accumulates in the column of casing to hold down the gas temporarily, causing the pressure to rise, and the contents to discharge through the lead line. The gas continues blowing after the oil has been expelled, until such time as the oil

Fig. 137. CASING AND PIPE-HEAD

rises high enough in the casing. Then, after a period of quiet, the flow is repeated. Eventually the gas pressure becomes so low that other means must be resorted to for inducing the flow.

Artificial Flowing of Oil Wells. In some localities, particularly where the gravity of the oil is low, the oil-string is pulled back to the top of the sand and the next smaller size inserted to the bottom. The latter, called the 'agitating-string,' is moved up and down by the calf wheels through a space of 50 or 75 ft. in order to enliven the gas, thus making a flow by capillary attraction in the small annular space between the strings. A tee is placed on the oil-string with a stand-pipe sufficiently high to prevent the oil running over, thus forcing it through the lead-line to storage. Where the gravity is light, the oil-string can be pulled back to the top of the sand and set on packing clamps, upon the next larger string, the latter having a collar (Fig. 137) with two 2-in. holes tapped and threaded, into which the lead-lines are screwed.

It is not unusual to see a well flowing between the strings at the same time that pumping is being carried on inside the oil string. A packing-clamp is also made similar to a stuffing box; it is screwed into the collar of the next larger size of pipe and the oil-string raised or lowered through it for 'agitation' purposes.

The swab is often used to start the flow by being run into the

Fig. 138. COMMON SWAB

Fig. 139. STEM SWAB WITH PLUNGER VALVE

Fig. 140. LARKIN HOOK WALL-PACKER

Fig. 141. LARKIN HOOK WALL-PACKER PUMPING TYPE, WITH GAS ESCAPE

well and rapidly withdrawn. With two bull ropes, a column of from 1600 to 1800 ft. of fluid can be lifted, but only in screw-casing, as the inside lap of stove-pipe casing would cause excessive leakage. The swab (Figs. 138 and 139), which is run on the stem, has a rubber ring placed over 3-in. pipe, the latter threaded at the lower end to permit tightening to expand the

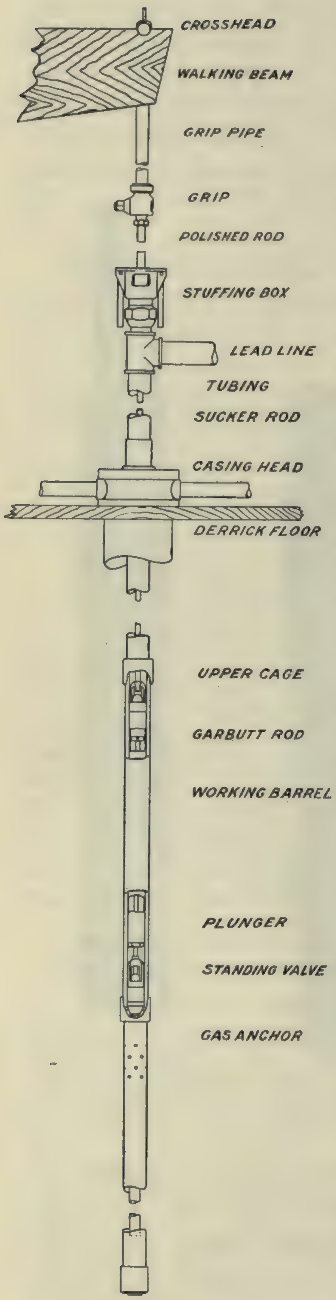


Fig. 142. OIL-WELL PUMPING OUTFIT

rubber to the bore of the casing. Holes are drilled through the body to communicate with the 3-in. pipe in order to permit passage of the oil when the swab is being run in. A vertical check-valve is attached to the bottom to prevent leakage when lifting the column. Swabs are also used to clear the perforations by drawing the sand or shale into the casing where it can be bailed or drilled out.

Bailing is often successful in inducing a well to flow, the bailer being run to bottom and rapidly withdrawn. This agitates the gas and causes the oil to flow. Again, a 2 or 3-in tubing with a packer (Figs. 140 and 141) is placed at a safe distance from the bottom to prevent its becoming sanded. The oil will then rise in the smaller column and often flow steadily. Care should be taken in placing the packer that no leakage occurs around it or that no passages are cut through the rubber later on, for once sand gets above it, considerable risk is attached to its withdrawal from the well. In fact, many operators prefer running on the tubing a swage-nipple of nearly the same diameter as the oil-string instead of the packer, for this reason.

Pumping. When a well has ceased flowing, or cannot be made to flow by reason of a low gas-pressure when the sand is first struck, it is usually put to pumping. This is the common method of extracting oil from the wells throughout nearly all fields. Pumping is accomplished by means of a deep-well pump, which is lowered on tubing to a sufficient depth to insure ample submersion, but in wells where the production is light the walking beam need only be run at intervals as the oil accumulates. The

size of the tubing is generally 3-in. with 11½-thread couplings, although 2 to 4 in. is used, the latter having 8-thread couplings. All tubing is heavier than the same sizes of line-pipe, and wells 4000-ft. deep may be pumped with profit. The actual lift of fluid, however, should not exceed 3000 ft., for at deeper levels the strain on the equipment is excessive, and parting of rods or tubing might result.

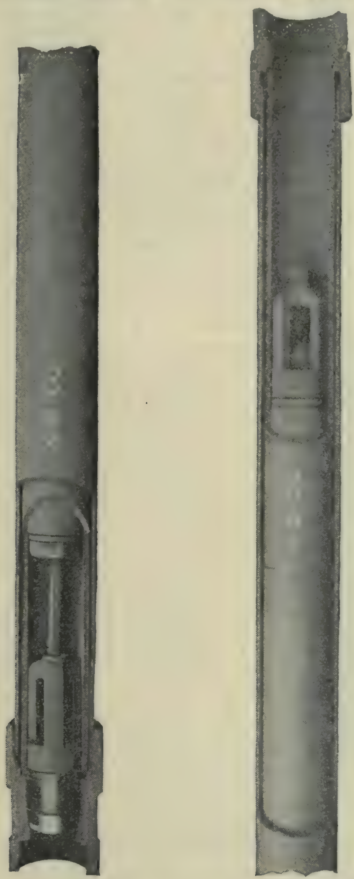


Fig. 143. SECTION OF PUMP OR PLUNGER WORKING-BARREL

Showing lower valve   Showing upper valve

The pump or working-barrel is from 3 to 20 ft. long, 6 ft. being the common length (Fig. 143). For a 3-in. working-barrel, the inside bore is 2¾ in., some manufacturers using a liner of this size rather than to bore the barrel itself. A hollow steel plunger, which closely fits the barrel, is equipped with a valve at the top, while a nut is screwed into the lower end, which supports the garbutt-rod when pulling the sucker rods. The garbutt-rod, ⅜ in. by 3 ft., has a three-winged nut at its upper end which rests upon the nut of the barrel. The lower end of the garbutt-rod is connected to the lower or standing valve and lifts the latter from its seat when the sucker-rods pull the plunger from the barrel. The standing valve is securely seated upon a beveled shoe or shoulder at the bottom of the working-barrel, having a long tapered sleeve for this purpose. Each valve consists of a round steel ball resting upon a seat and has three or four-wing cages to allow the balls the necessary play, at the same time acting as guides for their proper seating. The valves act as an ordinary check-valve when pumping is in progress, the 3-in. seat

having an opening of 1¼ inches. Some operators use two and often three balls when pumping wells making quantities of gas, the latter often holding the balls up and preventing the valve from lifting. In the eastern as well as some of the southern fields of the United States, where the percentage of sand is small, an upper valve as shown in Fig. 144, is substituted for the steel plunger. These valves have leather or linen rings as in the Lewis or Kinney pattern, or are wound with cotton or hemp rope as in the Landas pattern. Valves are also made which have a spring to keep the cups tight, expanding them fully to the working barrel. The Parker valve (Fig. 145) differs from the ordinary valve in that a plunger draws the valve up against the seat, which is placed above, making a positive action which is often successful in heavy gas-pressures as well as in handling sand.

Fig. 144. UPPER VALVE FOR WORKING-BARREL

The Parker pump has larger valves than those of the ordinary pump. It is better adapted to heavy sand and water conditions because of the positive action of the valves (Fig. 146) and the fact that both valves work close together, leaving the top end of the plunger open and cleaning the barrel of sand at each stroke, thus lessening the liability of the pump becoming clogged with sand.

The Futhie Hiveley pump (Fig. 147) is used in wells handling large quantities of sand and water; 2-in. tubing is used in place of ordinary sucker rods and the fluid, sand, etc., is raised through the 2-in. tubing, preventing the sand and water from wearing the plunger. Whenever the valves become clogged, the plunger is

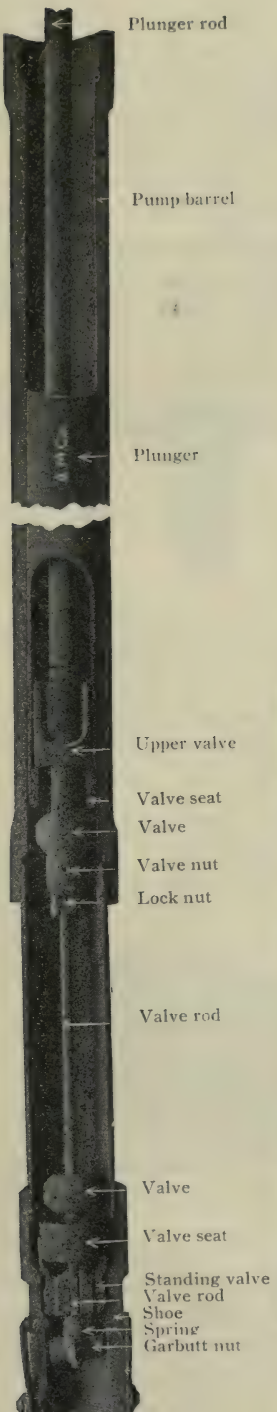


Fig. 145.
PARKER PLUNGER PUMP OR WORKING BARREL

Fig. 146.
VALVES IN PARKER PUMP

Fig. 147.
FUTHIE HIVELEY PLUNGER PUMP

set upon the standing valve and the two deflectors raise the valves, allowing the fluid to flow back, thus washing out the sand. In this way the pump can be cleared of sand without removing it from the well.

A string of sucker-rods, either wooden with iron connections or solid iron or steel, is used to work the plunger. The wooden rods (Fig. 148) which are used in the Canadian and some of the eastern oil fields of the United States are made of ash or oak from 1⅛ to 3½-in.,

Fig. 148. WOOD SUCKER OR PUMP RODS

Fig. 149. STEEL SUCKER RODS

Fig. 150. POLISHED ROD

with iron couplings from ⅝ to 1½ in. The iron or steel rods (Fig. 149) are 20 ft. long, from $^9/_{16}$ to 1 in. diameter, with ⅞ to 1¼-in. couplings, and are extensively used in all oil fields, being far superior to the wooden rods for pumping heavy-gravity oil or pumping through

small tubing at depths of over 1500 ft. The sucker rods are connected by a substitute to the upper valve cage and extend the entire length of the tubing to the polished rod (Fig. 150). The latter is $1\frac{1}{8}$ in. by 10 or 20 ft. and works through a stuffing-box placed in the tee at the top of the tubing (Fig. 151). It is held in place by a 2-in. adjuster-grip (Fig. 152) which can be loosened to raise or lower the string of sucker-rods as desired. The grip is screwed into 2-in. by 10-ft. pipe, the latter being coupled to a crosshead-

Fig. 151.
STUFFING BOX AND GLANDS

Fig. 152.
SINGLE ADJUSTER GRIP   DOUBLE ADJUSTER GRIP

tee which rests on top of the walking-beam. For deep-well pumping, temper screws are often left at the well and used in place of the 2-in. pipe and grip, while special pumping devices can also be purchased which are stronger and more reliable than the ordinary 2-in. pipe. The polished rod may extend into the 2-in. grip-pipe, thus making allowance for shortening or lengthening a string of rods, the stroke of the pump being from 18 to 36 inches. A

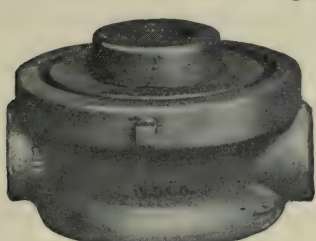


Fig. 153. TWO-WAY CASING-HEAD

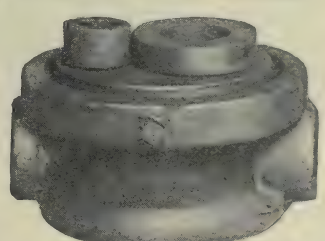


Fig. 154. TWO-WAY CASING-HEAD WITH TWO-HOLE TOP OUTLET

casing-head (Figs. 153 and 154) is attached to a nipple screwed into the top coupling of the oil-string and a recess in the top in which a plate sets. The plate has an opening large enough to admit the tubing-collar. When the last joint of tubing has been placed in the well, a tubing-ring large enough to cover the opening in the plate and having a hole small enough to engage the

tubing-collar is slipped over the joint and the tubing set upon the casing-head, gaskets having been previously placed under the plate and rings. The casing-head is a casting, having 2 or 3-in. outlets on the sides for oil or gas, the weight of the tubing upon the plate preventing their escape, forcing them into the line attached to the opening. Enough gas is usually collected in this way to fire the boiler or run the gas engines. A lead-line connected to the tee on the tubing conveys the oil to storage.

After the tubing has been set upon the casing-head, the plunger, with a standing-valve attached by the garbutt-rod, is lowered to the shoe of the working-barrel by the sucker rods. These are raised and lowered several times upon the standing-valve through a space of 1 to 2 ft. to insure that it is properly seated. The rods are pulled back sufficiently to prevent the plunger striking the standing valve when the full stroke of the beam is used. The wrist-pin is usually placed in the first hole of the crankshaft, making a pump-stroke of about 24 inches. On the upward stroke, the valve is closed and the plunger sucks in the oil, the standing valve being open. On the downward stroke, the upper valve opens, the lower valve closes and the plunger descends for another load. Gas-anchors placed on the bottom of the working-barrel often relieve the pressure on the valves; a joint of tubing is perforated with ¼ to ½-in. holes for 3 or 4 ft. near the barrel, and a plug screwed into the coupling at the lower end. A piece of 1½-in. pipe 5 to 10 ft. long is attached to the lower end of the standing-valve and extends below the perforations in the tubing. When the oil is drawn into the working barrel, it must travel through the perforations and thence downward to the lower end of the 1½-in. pipe before it can enter the pump. The gas, instead of following a downward course, rises outside the tubing to the casing-head.

When the plunger becomes worn, production gradually lowers to a point where a renewal of the pump is necessary. Nearly all oil carries with it more or less sand, which cuts and wears the plungers rapidly. Many wells, particularly in the fields of the Eastern and Southern United States, may be pumped for long intervals before renewals are required, while in some of the Western fields, it is not uncommon for the pump to last only a few days. A pulling-gang of three or four men is kept by every oil company to perform this work. When 'pulling' a well, the beam is 'taken down' by disengaging the pitman from the crank and lowering the end of the beam which points towards the engine house, so that the end inside the derrick

swings up and is out of the way. The rods are pulled, including both valves, three joints at a time. The tubing is pulled in stands of three joints and stood back in the derrick. This work requires the better part of a day where the well is being pumped at a depth of 2000 ft. Should the pump 'sand up,' the plunger is held fast so the rods and tubing are pulled together. This is a disagreeable task, as the tubing is always full of fluid and when a stand is unscrewed, the oil spurts over the floor. The bull-wheels are used for this character of work, except in deep holes, where the calf-wheels are sometimes employed.

Many pumping-wells do not throw oil out of the lead-line at every

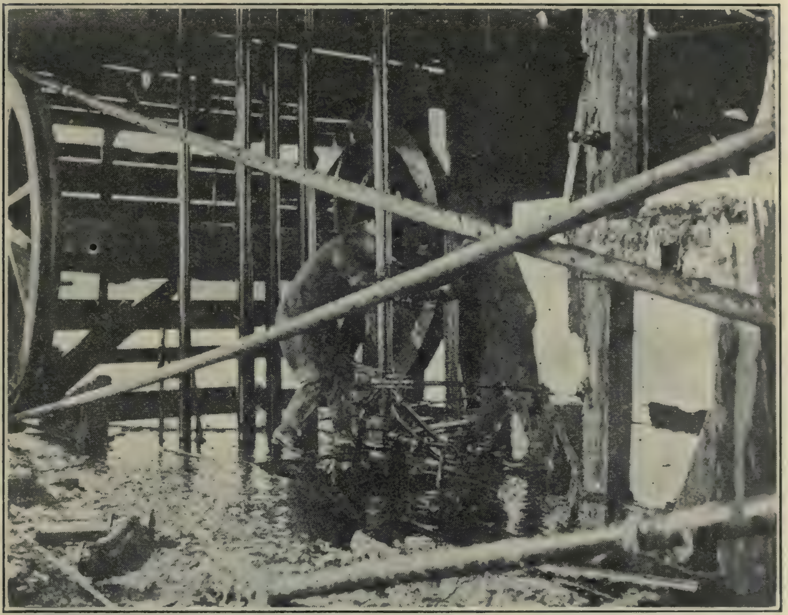


Fig. 155. UNSCREWING TUBING WHILE PULLING A 'WET' HOLE

stroke of the beam, for the gas usually expels the contents of the tubing at intervals when the weight of the column of oil has been reduced sufficiently by the gas to cause a flow. The sucker-rods by their movement, keep the gas agitated and cause the flow to be repeated, the valves often working intermittently to raise the oil. Again some wells will make a small production through the tubing without aid from the pump, while others require a constant agitation of the gas to cause the well to flow. Only by experimenting with each individual well can the right method be determined for obtaining the

maximum production. One well may produce satisfactorily with a packer or swaged nipple, another by compressed air, while a neighboring well may use pumps to the best advantage. There is no set rule as to the depth to tube a well for pumping, but in most instances the tubing should be lowered as near to bottom as possible without

Fig. 156. MODEL SAND PUMP OR BAILER

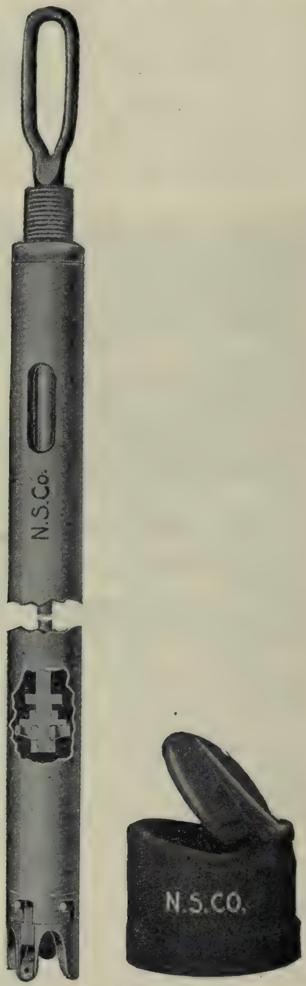


Fig. 157. LARKIN BAILER

danger of 'sanding up' the pump. Many wells, however, make more oil when pumped a hundred feet or so from the sand, while a few may require tubing several hundred feet up to obtain any production whatever. Sand-plugs or 'bridges' make their appearance in producing-wells and are removed from the casing by bailing or drilling. The

forms of bailers shown in Figs. 156 and 157 are successful for getting out the sand. The presence of water in the well is always a source of expense and annoyance, for it aids in bridging the sand and plugging the pump. Gas pockets often form in the pump-chamber, interfering with the action of the valves by being alternately ex-

Fig. 158. BAND-WHEEL PUMPING POWER

panded and compressed. This condition is hard to overcome, the gas-anchor not always preventing admission of gas to the working barrel. Constant improvements, however, are being made and it is to be hoped that this trouble will finally be eliminated.

Multiple Pumping. For pumping deep wells and wells which give considerable trouble from sanding, the walking-beam is used with steam, gas engines or electric motors, for power. Where the wells are grouped, particularly in shallow territory, it is customary to install multiple pumping-powers. The ordinary power (Fig. 158) consists of a horizontal shaft which, through bevel gearing, drives a vertical shaft upon which is placed one or more eccentrics. Holes are bored in the outer flanges of the latter, to which the jerker, or transmission-line leading to the well is attached. The jerker-line is pulled a distance corresponding to the throw of the eccentric at each revolution, producing a horizontal stroke of from 18 to 30 inches. The power is furnished by steam, gas engine, or motors and can be arranged to pump as many as 25 1600-ft. wells or 18 2500-ft. wells. The jack, made of iron or wood (Fig. 159), is placed over the well at the derrick-floor and securely fastened to the casing head or floor. The horizontal motion imparted by the jerker-line is changed to a reciprocating vertical motion (Fig. 160). Multiple pumping, wherever practicable, reduces the cost of producing oil very materially.

Compressed Air. The use of compressed air as a medium of lifting the oil has found favor in many oil fields, especially where the encroachment by water has rendered it impossible to obtain production by plunger-pumping or other means. The air-lift, however, is not satisfactory for raising oil of heavy gravity. The oil is so viscous that the air collects in large globules and finally 'blows through' the fluid without carrying the oil with it. On light-gravity wells, or on wells where the percentage of water is high, it works successfully, maintaining a large production at low cost. A slight drop in gravity generally results when a compressor is used. The ordinary compressor for blowing wells is of the compound type, capable of a maximum pressure of at least 500 lbs. and with a working of 350 lbs., while the output of air is about 300 cubic ft. of free air per minute under normal conditions. Mr. Edward A. Rix* says:

"In a test of air-lift systems in the Kern River field made by the Peerless company, pumping a mixture of water with 20% oil at an average lift of 470 ft., with an average submergence of 40% and an average length of discharge pipe of 800 ft., they found as the average of many tests, air-pressure, 152 lb.; free air per minute, 140 cu. ft.; gallons of fluid per minute, 93; cubic feet of free air per gallon of fluid, 1.5; ratio of free air to fluid pumped, 11. Ninety-three gallons of fluid per minute is equivalent to 3400 bbl. per day. The above

**Western Engineering*, August, 1912.

pumping was done through 3-in. tubing with $1\frac{1}{4}$-in. air pipes, and both the straight air systems and also two other so-called patented systems, with the result that no gain was shown by the patented sys-

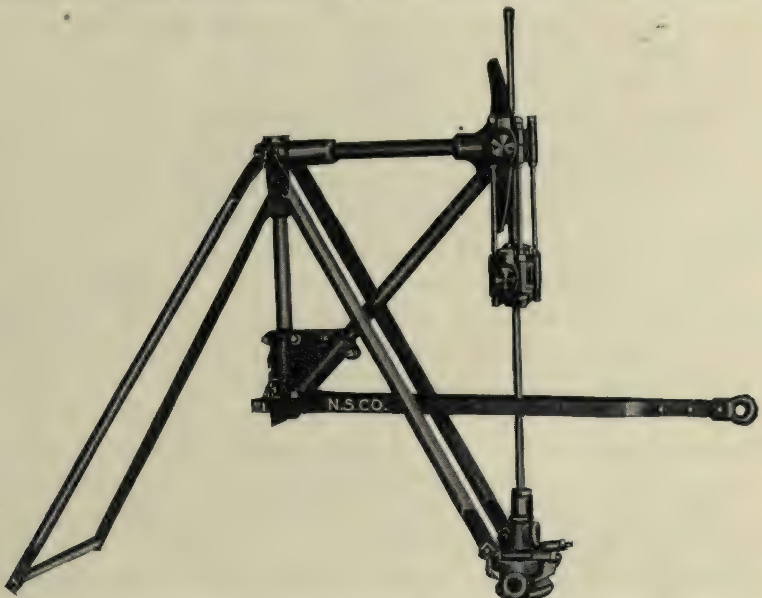


Fig. 159. JONES AND HAMMOND PUMPING-JACK

tems; and while on this subject it might be well to say that one well was piped as many as thirteen times, using the straight air system and after each piping better results were shown; in fact, the variation

Fig. 160. PUMPING WITH SIMPLE JACK

in pipe sizes and ratio of submergence, all within reasonable limits, show a marked variation in economy. The results show conclusively that not only the ratio of submergence, but also the relative amounts of air and water being pumped influence the economy; the gravity of oil also offers its troubles, and there is, over and above all these, the question of the size of the discharge pipe for the fluid, and it is a vital question. Too large a pipe is fatal, because the air slips by; too small a pipe is equally bad, because the air escapes and the expansion is checked. The proper size is a matter of experience based on an average velocity of from 6 to 8 ft. per second in the pipe or about 12 to 18 gal. per square inch of area of discharge pipe."

Various forms of air-lifts have been tried out, A. Beeby Thompson having successfully used an apparatus (Fig. 161) in which 4-in. tubing is placed to bottom with 10 ft. of ½-in. perforations in the lower joints and 2 to 2½-in. column inserted inside the 4-in. "to a depth in the fluid equal to at least twice the distance from the level of the liquid to the surface." An air-head is placed at the surface and the air is forced down the 4-in. tubing outside the smaller tubing and returns inside the 2 or 2½-in. tubing, forcing out the dead oil and later carrying up the aerated fluid. This form of air-lift has also been successfully used in the United States. The Associated Oil Co. in California used an air-lift as shown in Fig. 162. An ordinary plunger pump is often used in conjunction with compressed air when the well is making water, the pump being placed at a point above the water level where the oil contains little water. The air-lift raises the water with a small percentage of oil while the pump raises oil with a small percentage of water. Where water from one well is flooding the territory the air-lift is installed to protect the neighboring wells and the latter kept pumping, the reduced water-level making it possible to obtain more oil. In the Kern River fields, it was found by continuous blowing of the key well that production in neighboring wells was materially increased. In many cases, however, where there is no water present, the air-lift has not met with such pronounced success, but this can be attributed largely to lack of sufficient oil in the well to furnish a continuous stream. When the latter condition obtains, plunger-pumping is usually the only alternative.

Perforations. The question of perforations to be used in the oil-string is an important one. There is no rule governing the size or quantity in any particular oil field and in many cases only by repeated trial is a perforation found which gives a maximum produc-

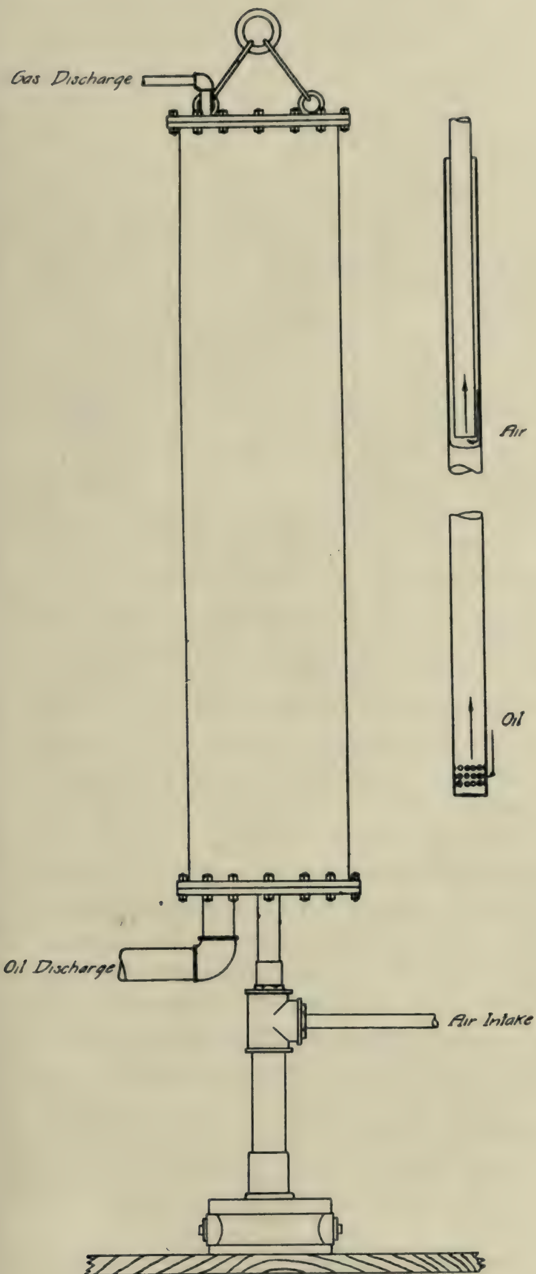


Fig. 161. THOMPSON'S HEAD-GEAR FOR COMPRESSED-AIR PUMPING

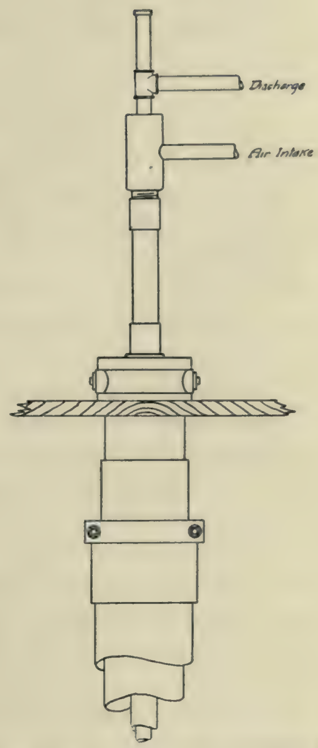


Fig. 162. STANDARD SURFACE CONNECTIONS FOR AIR-LIFT PUMPING

tion. The gravity of the oil, the amount of sand the well makes, the quality of sand, that is, whether fine or coarse, the presence of shale or mud and the percentage, if any, of water, all have to be considered. In light gravity oils it often happens that the perforations become clogged with shale or mud. This prevents the oil from entering the pipe, thus reducing production. This condition sometimes may be remedied by repeated swabbing, by moving the casing to remove the shale from the perforations, by washing the oil or, in extreme cases, by withdrawing the oil-string from the sand until the shoe is just above the latter, the light oil working its way through the cavings and up into the casing. In washing, the oil is pumped cold or hot down the tubing for a period of a half-hour or more, a 3-in. tee having been previously attached to the bottom of the tubing to force the flow directly against the perforations. Some operators pull the standing-valve out of the barrel and simply pump the oil down the tubing without lowering the latter. The well will show an appreciable gain until the perforations again become clogged, when washing is again repeated. Some wells require washing every few days, while others will pump satisfactorily for several weeks.

A low gravity oil usually carries a large percentage of sand, and when first put to pumping often occasions considerable expense and trouble until the percentage of sand is reduced by reason of a cavity formed in the sand around the oil-string. If the sand is fine, with a small percentage of water present, repeated sanding of the pump occurs and there is no perforation which will help this condition, continued bailing being the only means of removing the sand. In some of the Russian fields the wells cannot be pumped because of an excessive quantity of sand, and production is obtained only by steady bailing. Should the sand be coarse, however, different makes of screens or screen-pipe have been devised whereby the sand is excluded from the casing, allowing the oil to come freely through the interstices. In one form, the pipe is wound with a tapered wire over ½-in. or ¾-in. round holes, the wire preventing large particles from entering the pipe, while in another, the holes are plugged with 'buttons' having small slots, which answer about the same purpose as the wire. Wells in California producing from 20 to 40 barrels a day have been increased in production to 100 to 250 barrels a day, while in the southern fields of the United States the use of this pipe is almost universal.

For ordinary producing wells in California, where the gravity of oil is light, ⅜ to ⅝-in. round perforations are used, ½-in. being the common size. The holes are bored with a drill, each joint having

three to six rows, from 4 to 12 in. apart. Many operators prefer perforating the casing with slotted holes, in the well after it has been landed (Fig. 201), the holes being ¾ by 1½-in. for heavy oil and ⅜ by ⅝ for light oil with three or four rows to the joint. Should an oil-string become frozen while drilling into the oil-sand, it can always be perforated in the well.

Shooting Wells. Where the formation containing the oil is hard, such as the limestone and sandstone found in the fields of the eastern and central United States, a better production is often obtained by blasting the oil-bearing rock. A high explosive, such as nitro-glycerine, is carefully poured into long cylindrical cans made for the purpose. The depth of the well to the oil-bearing strata is first carefully ascertained and the charge lowered to the desired position. A firing-head is placed at the top of the upper can and a 'go devil,' a piece of cast iron with wings for a guide, is dropped upon the firing-head. After the blast, the hole is thoroughly cleaned out, leaving a cavity in the oil-formation where the oil may gather. The production in a well with hard formation is usually increased appreciably by shooting, but care should be exercised in the quantity of explosive used, for an excessive charge may result in breaking the formation to such an extent as to ruin the well. The usual shot is from 10 to 300 quarts of nitro-glycerine, depending upon the formation. A shale or soft stratum may be so compacted by a blast that the oil cannot penetrate it. Shooting has been tried in the 'tight' oil-sands in California but with indifferent success.

Dehydrating Oil. When water is present in a free state in oil, it is easily separated by heating with steam. The latter is piped into a storage tank in 1 or 2-in. coils, the coils being placed horizontally from 4 to 6 in. from bottom. They should be kept covered with water in order to prevent the hot oil from adhering to them. A temperature of 100 to 150° F. is usually sufficient to cause the water to settle to the bottom, where it is drawn from the tank by a valve placed for the purpose. Should the oil be emulsified, the problem of separating the water is not so simple, additional equipment being necessary for the purpose. An emulsified oil is one in which the water portion carries a mineral salt in solution, the latter acting as a saponifying agent and surrounding the globule with a membrane or skin which sometimes cannot be broken by steaming, even at the boiling point. The emulsion is reddish brown in color, has a jelly-like appearance and is extremely viscous. The belief that it contains shale or other foreign matter

is erroneous, although its appearance as a mass is deceiving. It often runs as high as 75% in oils, although the latter percentage undoubtedly contains a great deal of free water. A 35% emulsion, however, is common and quite as difficult to separate as are the higher percentages. The problem that confronts the operator is not only one of breaking up the globules by rupturing the encasing membrane, but in saving the volatile portions of the oil, which naturally tend to evaporate under the extreme heat conditions necessary. Four systems which have been successfully and economically used will be described.

1. Dehydrating by Electricity. This method, known as the Cottrell process,* has been successfully used on emulsions of varying proportions. The oil is first allowed to flow through the wetted septum water trap *A* (Fig. 163), and during its passage through this trap the free water is deposited on the wetted septum 2 and passes down it to the bottom of the trap and so away through outlet 3, which is so adjusted as to height as to make it self-regulating. The desired oil level in the trap is maintained by means of float valve 1, which controls the supply. From this trap the oil and water emulsion is discharged through outlet 4, whence it is taken by the rotary pump 5 and delivered to the treaters *B*. In cases where the contour of the ground permits, the wetted septum water trap may be placed at an elevation above the treaters, thus securing gravity feed and making rotary pump 5 unnecessary. The wetted septum 2 is merely a pervious canvas bag which has been thoroughly wetted with water, and is long enough to reach below the permanent water-level in the lower element of the trap. Under these conditions the canvas has an affinity for water, but not for oil. When the mixture of emulsion and free water, in its passage through the trap, reaches the canvas, the emulsion passes through, while the water, for which the canvas has an affinity, is deposited on and drawn down the canvas to join the main body of water. The treaters *B* consist of a sheet-metal tank 6, cylindrical for the major part of its height, but having an inverted conical top portion 7. The object of this increase in diameter near the top is to lengthen the distance between the electrodes along the surface of the oil, and thus prevent surface leakage.

An outer electrode is formed by tightly stretching a number of wires 8 from a ring 9 at the base of the inverted cone to a

Western Engineering, April. 1912.

circular plate 10 fastened to the bottom of the tank. Outside this electrode is a wetted septum 11. An inner electrode is formed by tightly stretching wires 12 between two circular plates 13 suspended in the tank by vertical shaft 14. The wires of the inner

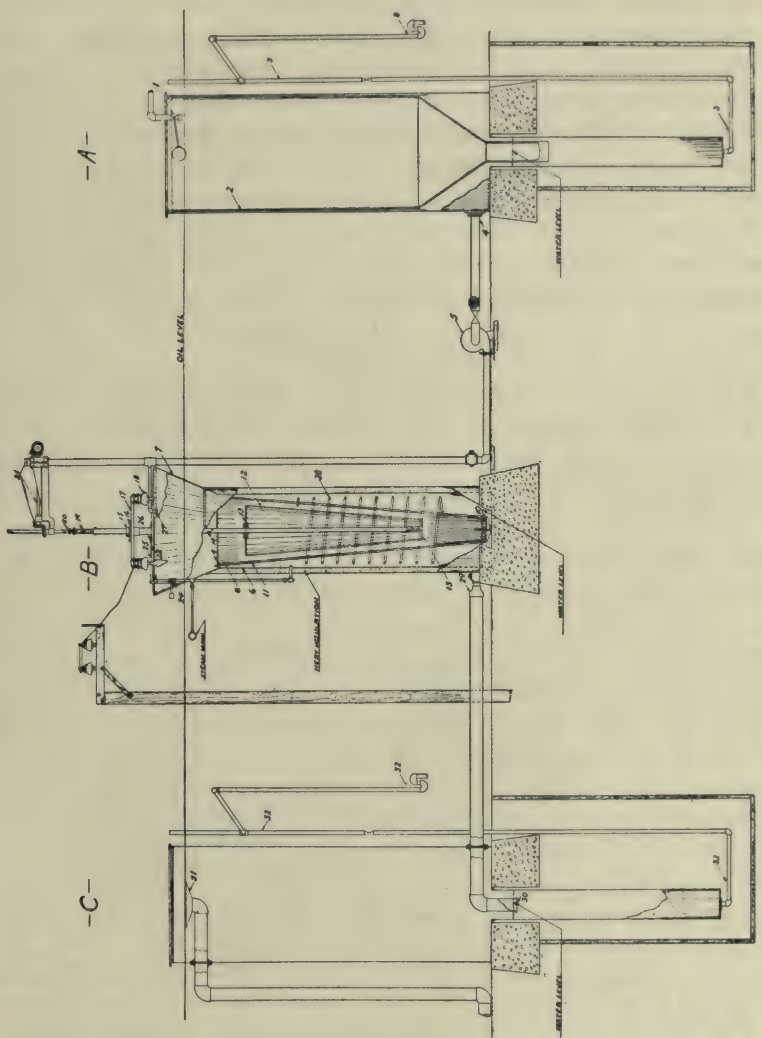


Fig. 163. APPARATUS FOR ELECTRICAL DEHYDRATION OF CRUDE PETROLEUM

electrode are parallel to, and exactly concentric with, the wires of the outer electrode. The inner electrode is supported by a clamp 15 on the shaft 14, riding on a bearing saddle 16, which in turn is supported by the channel-iron frame 17 on insulators 18.

The vertical shaft 14 is rotated through insulating shaft 19, and universal joint 20 by the shaft and gearing 21, the latter being operated by a small electric motor.

The treater has a cover 22 with a large circular opening in the centre through which the inner electrode passes. The top ring of the treater is made of pipe which is perforated with a large number of holes pointing horizontally, and which is connected through valve 24 to a steam supply; this valve is normally held closed by wire 25 and fusible link 26, but in the event of the oil in the treater catching fire, the fusible link will melt, releasing valve 24, and so filling the space below the cover with steam and choking the fire out. The oil enters the treater at inlet 27 (the flow being regulated by the size of the inlet orifice), and is maintained at a suitable temperature, depending on the viscosity, by means of a steam coil 28. After treatment the oil and water are discharged through outlet 29 and proceed to the separator *C*.

The inner electrode is connected through the saddle and frame with a source of electricity at a voltage between 10,000 and 15,000. The action of the electricity is to create a strong electrostatic field between the electrodes. As the emulsion under treatment comes between these electrodes the infinitely small particles of water, being conductors of electricity, will be formed into chains from electrode to electrode along the electrostatic lines of force, and, if the voltage be sufficiently high, the fine films of non-conducting oil between the water particles will be punctured, bringing the entire chain together in the form of one comparatively large drop. This drop is now free water and is deposited on the septum 11 and conveyed to the bottom of the treater. It may happen, however, that so many chains of water particles are formed at the same instant, that they constitute a short circuit between the electrodes, thus lowering the voltage below that point at which it can puncture the oil films. In order to prevent such short-circuiting, the inner electrode is rotated, which gives the desired result, probably owing to the lengthening of the chain between corresponding wires in the outer and inner electrodes as the latter is revolved.

The separator *C* is merely a device for quickly and automatically separating the oil and water. The mixture enters at inlet 30, and the clean oil rises and flows away to the delivery tanks through outlet 31, while the water drops and is discharged through pipe 32 in a clear stream. As in the case of the wetted septum trap, the height of outlet 32 is so adjusted as to make the

flow self-regulating, the controlling factor being the water-level in the lower element of the trap.

2. *Dehydrating by Direct Heat.* There are many variations of this method in use, but the principal objection to most of them is the lack of provision for preventing loss by evaporation. A system which has been patented, however, overcomes this objection and can be used at a cost of 3 to 4 c. per barrel including a royalty of 1 c. per barrel, the cost of installing the separator being about $1500. The oil to be treated enters a series of four or six 12-in. pipes connected by return bends and placed in sets of two about 30 in. above the furnace floor. The back ends of the inside walls have a flue space 12 in. wide and the heat runs the entire length of the furnace through the flue space and up around the evaporator which is bricked in, leaving an open space of about 6 inches. The evaporator is a cylinder 4 by 20 ft. of $^5/_{16}$-in. steel having a conical bottom and resting upon a foundation of brick. The oil is heated in the retort to a temperature of from 375 to 425° F. and passes through a 4-in. line into the top of the evaporator. Inside the latter are five baffle plates made of galvanized iron, having deeply serrated edges and projecting within 1 in. of the side of the evaporator. The baffle plates are held in the centres by lock nuts on a 6-in. pipe which has four large openings immediately below each plate. The latter are perforated with ¼-in. holes except the top one, which is solid. The oil, upon being introduced into the evaporator, strikes the top plate, spreads to the sides and runs down the evaporator in a thin film, the perforated plates preventing the oil from entering the openings in the 6-in. pipe. At such temperatures as 400° F. the volatile parts of the oil and the water are in the form of vapors, and enter the openings in the 6-in. pipe as such, while the non-volatile parts, including the mineral salts, continue their downward course and are drawn off at the bottom of the evaporator. The 6-in. column has three take-offs which convey the vapors out the side of the evaporator and into the discharge-lines. Both the outgoing oil and the vapors are run through pipes which are enveloped with larger-sized lines which convey the oil entering the retorts. Thus the heat of the outgoing fluid is absorbed largely by the incoming fluid, effecting a considerable saving in heat units, at the same time effectually cooling the treated product. The vapors are further condensed by being gravitated through a water jacket and enter a tank separate from the residuum, where the

water and emulsion can readily be drawn off. The 'tops' or lighter portions, can then be mixed with the residuum and the whole shipped to the purchaser. A unit plant will readily clean 1500 or 2000 bbls. of oil a day, leaving no traces of emulsion, and it will be found that the gravity has been raised from ½ to 1° due to the fact that the emulsions have been eliminated. The temperature should not exceed 450° F., the latter heat being more than sufficient to break up the emulsions and vaporize the water. The treated oil should be gravitated after entering the evaporator, as the latter should never have a pressure exceeding 25 lbs. per square inch. The retorts and larger lines can be made up from discarded casing to reduce cost, and tees should be used in place of elbows when the percentage of mineral salt is large, as the latter is apt to clog the lines at the turns after being liberated from the water. A steam connection at each tee will keep the bends clear. This system can be used successfully on any emulsified oil with an occasional replacement of the retorts which burn out in time.

3. Dehydrating by Compressed Air. The Milliff dehydrating system has met with success in treating emulsion by the use of compressed air. An air pressure sufficient to overcome the weight of the oil is maintained by an air compressor through a 3-in. line which passes under a boiler furnace at which it is heated to a temperature of 1000° F. The heated air is conveyed through an insulated line to a tank 8 ft. diameter and 20 ft. high at which it enters at the bottom. A fire screen is used in the line to prevent hot cinders or sparks from coming in contact with the oil, and a thermometer is placed near the tank for temperature readings. The air enters the tank at the bottom through a spider with four 3-in. wings having $^1/_{16}$-in. holes and intermingles with the oil in the form of globules of varying size. The heat from the air attacks the water, turning it into steam, at the same time liberating the oil from the emulsion globule and carrying the steam upward to the surface, where it is dissipated into the atmosphere, at the same time dropping the excess water to the bottom in a free state where it can be drawn off. One set of heater pipes in the boiler-furnace cleaned 140,000 barrels of oil at the Port Costa pumping station of the Associated pipe line. The oil contained an emulsion of 30 to 60% and tested less than 1% after treating by this process.

4. Dehydrating by Indirect Heat. In cases where the emulsion is not too refractory, the oil may be pumped into the bottom of a tank 8 by 20 ft. through a spider with from

$\frac{1}{8}$ to $\frac{1}{16}$-in. holes. About 500 ft. of 2-in. pipe for a steam coil should be used, and the tank should contain at least 10 ft. of water, which should be heated and maintained at a temperature of from 150 to 200° F. As oil and water have different coefficients of expansion, they will separate upon going through the heated water, the oil rising to the top while the water mingles with that below. The latter can be drawn off whenever necessary, to keep a level of about 10 feet. These methods are all continuous, and can be installed in units large enough to dehydrate 500 to 20,000 barrels of oil a day.

Handling Oil. In pumping-wells, or wells flowing at a moderate rate, the oil can be pumped to storage without appreciable loss if the proper precautions are taken. All pipe lines of the gathering-system should be laid in trenches and buried sufficiently deep for protection from heat or cold. As it is usually the custom to gauge each well separately for its production, tanks are installed at each well and the oil measured there before being pumped to storage. These tanks are usually from 25 to 100 barrels capacity, one or more being placed at each well, depending upon the amount of production. If the well is making sand, a box with baffle boards is placed upon a scaffold so that it discharges into the tank and the lead-line from the pump runs into it. The sand can be shoveled out of the box, to prevent it from entering the tank. If the well makes water, it can be partially drained at this point. By the use of tanks and sand boxes, the running of oil into earthen sumps can be avoided and a great deal of oil saved from loss by seepage and evaporation. Tanks should have close-fitting covers made of boards and roofing paper to prevent loss of the more volatile constituents. The use of tail pumps is to be recommended where the oil cannot be gravitated from the well. They are made of worn-out working-barrels with a standing valve below and a leather cup-valve above and are bolted to the main sill in line with the outside end of the walking-beam. A polished rod extends to the beam, as in the case of the oil-well pump; the tail pump has a 3-in. suction running to the well tank and discharges into the gathering-system, a check-valve having been placed in the latter to eliminate back-pressure. Instead of removing the tail pump when the tank has been emptied, a by-pass may be installed so that by closing the discharge gate and opening the by-pass gate the remaining oil circulates with each stroke of the beam and keeps the pump from becoming dry. The tail pump can be used only

upon wells making a production up to 350 barrels. A steam pump becomes necessary on a larger production.

Some operators use a water-covered storage-tank with the sides protected by a wooden cover to prevent evaporation in light gravity oils, while others paint the outside of the tanks white to reduce the intensity of the sun's rays. The large shipping tanks in any case should be well protected and the oil discharged from the gathering-system into the tank through an overshot which should run within a few feet of the bottom. For a production of 1000 barrels per day two 2000-barrel tanks are sufficient for storage, while for a production of from 5000 to 6000 barrels 5000 to 10,000-barrel tanks are used. In cases where it becomes necessary to store oil or where a gusher may be expected, 55,000-barrel tanks are built, but where the oil is kept moving daily in small shipments, they are hardly necessary. All shipping tanks are equipped with three or more sampling cocks placed at proper intervals on the side, and the suction line to the pump is usually 16 in. or more from bottom to prevent the sludge and water from being delivered to the purchaser. A swing-pipe is generally used on the inside end of the suction so that oil can be drawn from any level. The area of the heater-coil and all dead-wood is subtracted from the tank at the time that it is measured or 'strapped.' The latter is done by taking the mean of three measurements of the outside diameter and a corresponding number of the height, and reducing the result to barrels of 42 gallons. This is the basis upon which the purchaser buys the oil; a gauge sheet is made for every 1/8-in. and a copy given to the seller.

Upon obtaining a full tank of oil, the gauger of the purchasing company 'thiefs' or samples it at three or four levels, the samples being placed in different receptacles. The 'thief' is a specially made bucket which can be lowered to a certain point and a sample of oil taken from that particular level. Samples are usually obtained at the bottom of the discharge, at the top of the oil and two intermediate samples at equal distances. These are taken to the test-house, where, after shaking, 50 cc. of oil from each is poured into a 100-cc. burette and 50 cc. of gasoline added. After being thoroughly mixed by shaking, the burettes are placed in a 'centrifuge' capable of making 1000 to 3000 revolutions per minute and revolved for 20 minutes. The centrifugal motion throws the base sediment and moisture to the outside or bottom point of the burette; the readings are taken and multiplied by two, there being 50 cc.

of oil to 100 cc. of fluid. The limit of water and base sediment is usually 3% and anything in excess of that figure is rejected. The temperature and gravity are taken by pouring parts of each of the samples into a hydrometer-jar and a reading taken. In heavy oils, some purchasers use one-third each of carbon-bisulphide, which 'cuts' the asphaltine oil and gasoline.

Shipping is usually done by a steam pump large enough to overcome the line-pressure; electric pumps are also used for this purpose. Whenever possible, it is always desirable to have shipping tanks at the lowest point of the property, in order to take advantage of a gravity flow, thus effecting a saving in pumping power. The use of concrete reservoirs for oil storage is not always satisfactory, as it is difficult to build a large reservoir through which the oil does not seep to some extent. It is often necessary to run water into concrete reservoirs to save the oil, the seepage sometimes amounting to hundreds of barrels per day. Oil should be shipped as soon as possible after being produced, as the evaporation, especially in warm weather, is excessive. Oil standing in open earthen reservoirs has been known to shrink as much as 40% in the course of from 15 to 20 days. Oil, between 33 and 34 gravity, standing in tanks and exposed to the open air for 24 hours, has been known to lose 4% of its original volume by evaporation.

Gas Traps. The gas coming from the casing-head is usually caught and used under boilers or in gas engines, but the gas coming through the lead-line with the oil is often allowed to go to waste.

To prevent this, a gas trap as shown in Fig. 164 can be installed near the derrick. This trap consists of a sealed tank of about 25-barrel capacity. The oil enters the tank through a check-valve and is drawn off through a 3-in. outlet which has a float pressure-valve to regulate the discharge. At the top, a relief-valve is placed to protect the tank from excess pressure, while the gas is drawn off below through a 2-in. line. This trap works satisfactorily on wells of moderate pressure working no sand.

The McLaughlin automatic gas trap (Fig. 165) is designed to recover the gas from a well under more difficult conditions, especially where there are quantities of sand and water present. The oil, sand and gas enter the device through the lead-line *'H'* which leads directly from the well. The end of this lead-line is fitted with a tee into which is screwed a nipple *'M'* about 4 ft. long. On the upper end of this nipple is fitted a cast-iron valve *'A.'* The

faces of this valve are segments of a sphere. This valve engages a cast-iron valve *'B.'* The valve seat is riveted to a movable tank *'C.'* The movable tank *'C'* is suspended from a beam *'D'* and is counter-balanced by the weight box *'E'* filled with scrap iron. The beam *'D'* is supported by a frame *'F.'*

When in operation, the oil, sand and gas flow from the well through the lead-line *'H'* into the trap at the point marked '4-in. oil inlet.' Before oil flows into the trap, the valve seat *'B'* is held firmly against the valve *'A'* by the action of the counterweight *'E.'*

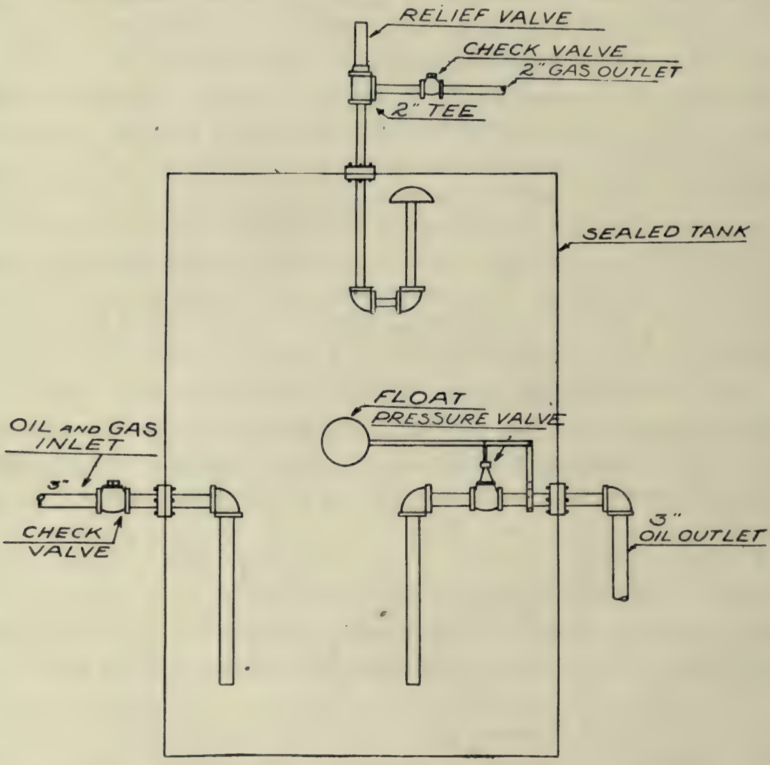


Fig. 164. STANDARD GAS TRAP

As soon as a sufficient amount of oil has entered the trap to over-balance the counterweight, the tank *'C'* carrying the valve seat *'B'* moves downward and allows the excess of oil and sand to flow out between *'A'* and *'B.'* In the meanwhile all gas has been disengaged from the oil and flows out through the gas line connection *'G.'*

On a steadily flowing or pumping-well, the trap reaches an equilibrium so that the oil flows out continuously at the bottom and

the gas at the top. On a head well the trap valve opens and closes rhythmically, maintaining at all times a perfect seal. The unbalanced upward pressure of the gas is sufficient to maintain, at all times, an oil seal of from 1 to 2 ft. in the bottom of the trap.

Other gas traps, similar in design, are made of three or four joints of casing, which is held in a nearly vertical position by guying to the derrick. The oil and gas enter the trap below, the gas rises to the top of the trap where it passes into a 2-in. line, while the oil is drawn off below. In some of the Russian fields, where production is obtained only by bailing, the use of the above-described gas trap

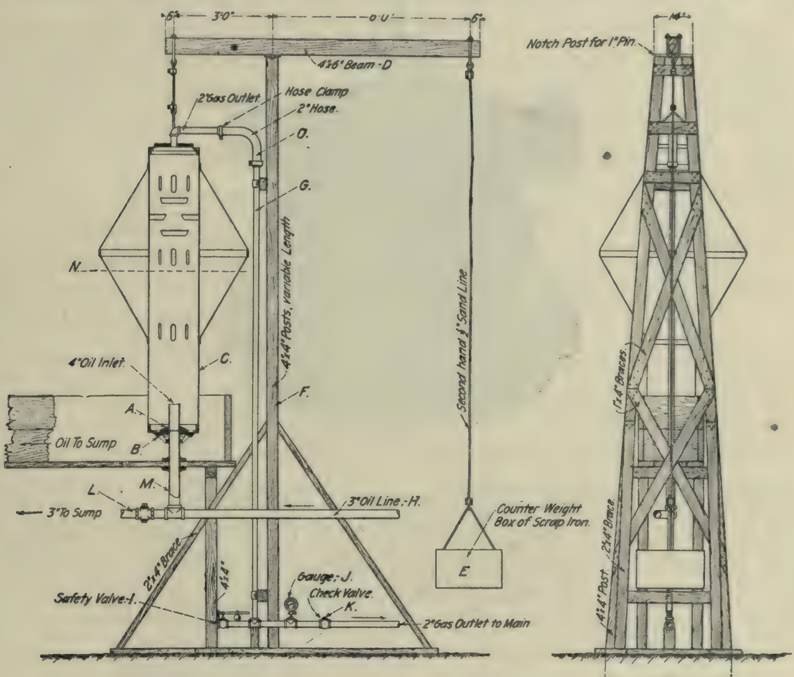


Fig. 165. THE McLAUGHLIN AUTOMATIC GAS TRAP

is impossible, by reason of the casing being open at the surface. The gas is then caught by perforating the inside string 100 or 200 ft. below the surface and sealing the annular space between the two inside strings. A gas pump (Fig. 166) creates a suction, drawing the gas through this space and into the receiving line. The gas may also be obtained by tapping a hole through all the casing to the inside string 15 to 25 ft. below the surface and pumping out with a gas pump.

As the bailer is being constantly raised and lowered, more or

less air is also caught, but considerable quantities of gas are saved. 'Bleeders' or traps should be installed in the gas line to drain off any water or gasoline that accumulates, thus keeping the gas flow open. The amount of gas varies from a few feet per day in old pumping wells to several million feet in gas wells, and where several wells are connected, check-valves should always be placed

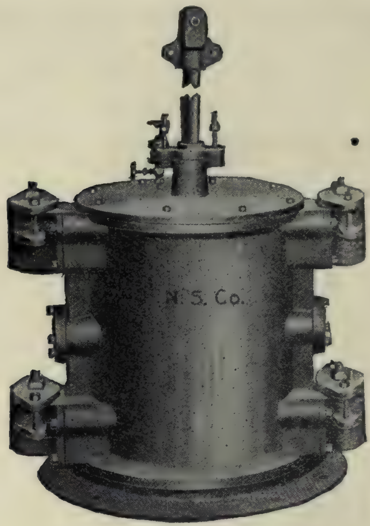


Fig. 166. GAS PUMP

in the line to prevent a high-pressure well from forcing its gas into a low-pressure one. Gas lines and traps should be installed with as much care and foresight as the steam lines or water lines, for a great saving in fuel is effected by conservation of the gas, as far as is possible.

CHAPTER VII.

FISHING TOOLS AND METHODS.

Unlike many branches of engineering in which the time occupied in the various stages of the work can be closely estimated beforehand, the drilling of wells may be delayed by many conditions that could not have been foreseen. The most vexatious, as well as hazardous of these are occurrences that lead to 'fishing jobs' for the recovery of tools or casing lost in the hole. Such problems may meet with prompt success or may drag along over a long period, for the units of time necessary for many drilling and fishing operations are often days instead of hours, and in this work, as with the original nimrod, Isaak Walton, patience never ceases to be a virtue.

While the loss of tools is accepted as a logical hazard that is bound to occur with greater or less frequency in such work, yet the care and attention to details that finds its reward in all engineering enterprises are especially valuable traits in this occupation, and frequent examination of equipment is unquestionably the greatest single factor in lessening the number of these difficulties. To this end the drilling and sand-lines should be watched carefully for signs of weakness or unusual wear, drilling tools should be scrutinized for incipient cracks, especially at welds, and no tools or equipment run into the hole unless, as far as can be detected, they are in perfect condition.

Equally important are the steps that may be taken in anticipation of the inevitable fishing job, such as calipering the diameters of the different parts of each tool, the internal and external diameters of bailers, etc. Such information may be readily obtained and noted in the casing tally-book, and when needed at all, is likely to be of the greatest importance and assistance.

Fishing for Lost Tools. It would be impossible to describe all the fishing tools that find use in drilling operations. Many are made for some particular purpose or use in a well where peculiar conditions exist, and when that work is finished they are discarded

or remodeled into something else, and heard of no more. Others find a wider application and more general use and so new types of tools and adaptations of old ones are being constantly introduced. For this reason this chapter will attempt, not to give a complete summary of all fishing tools, but rather a review of the more common accidents, with the principles of remedial measures and their applications.

Fig. 167.
LONG-STROKE JAR FOR FISHING

Tools for fishing are run in and out of the hole either on the drilling-line or on tubing. In either case they are attached, as is the bit when drilling, to a string of tools that differs from the ordinary drilling string only in the fact that the stem is placed above the jars instead of below, and the jars (Fig. 167) used have a longer stroke than have the common drilling jars. Both changes are made for the purpose of being able to deliver a more powerful blow on the up-stroke of the walking-beam, known as 'jarring,' when an ordinary pull with the drilling-line will not dislodge and loosen whatever has been caught with the fishing tool.

A useful accessory, when there is some doubt as to the position or size of the material lost in the hole, and a question as to the proper tool to run for it, is the 'impression-block.' This is a round piece of wood, about 2 ft. long, of such diameter that it travels easily inside the casing or hole, and is made concave at the lower end. A few nails project from the concavity, serving to hold in place a mass of fairly soft soap, so that when the block is lowered in the hole, either on the bottom of a bailer or attached by a pin to the bottom of the jars, until it is stopped by an obstruction and then pulled out, the indentations in the soap supply a fairly intelligible record of what must be grasped by the fishing tool.

The fundamental principle on which is based the majority of tools for fishing is that of running down, either on the outside or the inside of what is to be recovered, a device containing one or more obliquely-sliding plates with milled or tooth edges, so placed that when the fishing tool is situated beside the lost tool and then pulled up, these edged plates, known as 'slips,' en-

gage with the lost tool and cling to it while being pulled out (Fig. 168). This principle is applied widely in a great variety of fishing tools for recovering lost tools, rotary drill-stems and for dislodging frozen casing.

Probably the most common mishap that occurs in drilling a well is that due to a break in the drilling or sand-lines. If this has not happened directly where the line is attached to the tools or bailer, it is recovered by either the common rope-spear (Fig. 169), in which the wickers or spurs for the line point out from

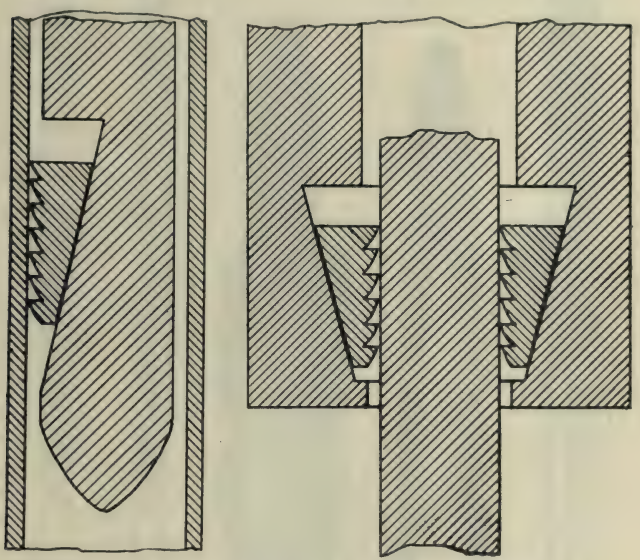


Fig. 168. PRINCIPLE OF FISHING TOOLS

a single bar, or the rope-grab (Fig. 170) with the wickers pointing in from two or three bars that spring sufficiently to press against the casing or the sides of the hole. The grab is also used where pieces of loose rope or wire are to be caught and withdrawn. In some cases the lost tools become lodged at the bottom of the hole so tightly that they cannot be freed by pulling with the rope-spear, and it becomes necessary to break the drilling-line at the point where it enters the rope-socket before the tools may be loosened by some other method. This is done, after the rope has become entangled in the rope-spear, by lowering the fishing-tools until just sufficient slack is in the lost line so that when the

fishing-tools are given the walking-beam motion, the lost line becomes taut at the high point in the swing of the beam. They are then jarred, sometimes for several days before the slight jar applied to the lost line at each stroke of the beam eventually breaks the lost line at the socket.

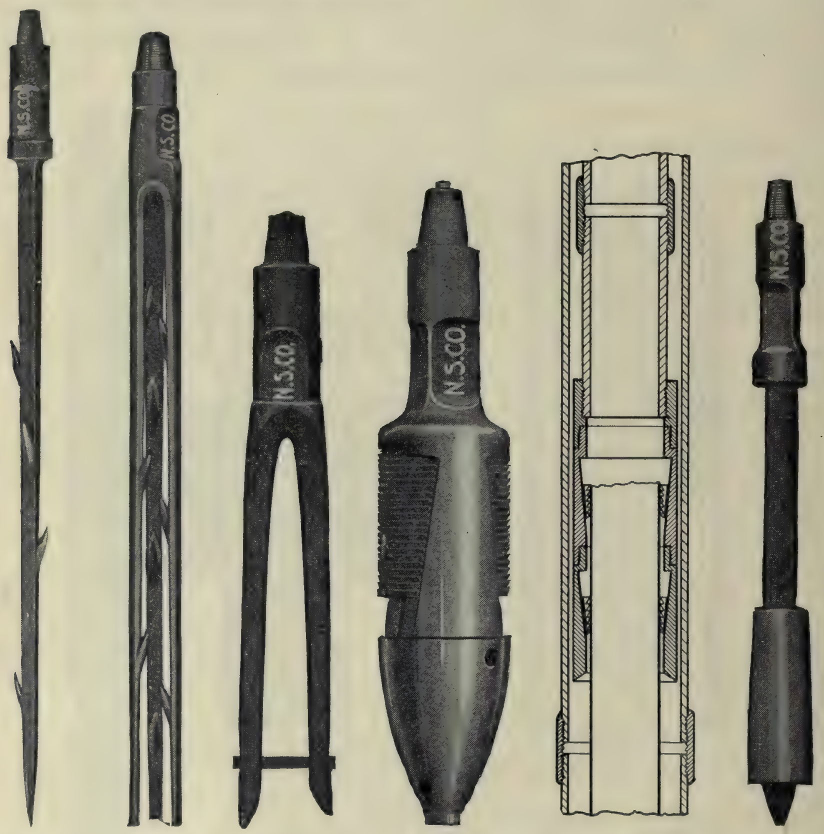


Fig. 169. Fig. 170. Fig. 171. Fig. 172. Fig. 173. Fig. 174.

Fig. 169—CENTRE ROPE-SPEAR. Fig. 170—THREE-PRONG ROPE-GRAB. Fig. 171—LATCH-JACK. Fig. 172—BULLDOG-SPEAR. Fig. 173—CASING-BOWL GRASPING TOP OF BAILER. Fig. 174—BELL OR MANDREL-SOCKET.

In cases where the sand-line has broken and the bailer is held too tightly to be pulled out by the rope-spear, the line is jarred as described above, until it is pulled away from the bailer, either alone or bringing with it the bail which not infrequently pulls away from the body of the bailer. If the bail remains intact a latch or boot-jack (Fig. 171) is run. This is a fork-shaped tool,

often made from the upper half of an old set of jars, with a small bar or latch at the lower end, swinging on a pin set in one of the forks. When horizontal it rests at the other end in a recess in the second fork. When this is run for a bailer and the lower ends of the forks are passing the bail, one on each side of it, it pushes up the latch and goes by it. The latch then falls back to a horizontal position and holds the bail when the fishing-tools are pulled up. The latch-jack is also often used for the work customarily done by the rope-spear, when the latter is not available, by running it in and driving the rope down until the coils have become tangled in the forks and latch so that they hang to it while being withdrawn.

Occasionally the bail may be pulled away in the course of trying to jar the bailer free, leaving the body of the bailer still in the hole. In such a case an ordinary bulldog-spear (Fig. 172) may be run into the bailer and jarred, although this step is seldom successful, as the spear is more liable to split the pipe of which the bailer is made than it is to dislodge it. When conditions permit, a casing-bowl (Fig. 173) large enough to run over the bailer may be tried and if this fails a bell, or mandrel-socket (Fig. 174) may catch the bailer. The bell-socket is essentially a bar or mandrel with an enlarged end, and a hood or bell-shaped piece that is free to move up and down on the mandrel. When used for fishing a bailer, the ball on the end of the mandrel enters the body of the bailer and the fishing tools are jarred down, forcing the bell down over the top of the bailer so that it takes the shape of the inside of the bell. When the tools are pulled up the mandrel passes up through the opening in the bell until the ball at the end of the mandrel reaches the inside of the bent portion of the bailer (Fig. 175), which is then grasped between the ball and the bell and is pulled out. This socket is also of considerable value when fishing for broken and odd-shaped pieces of tubing or loose pieces of casing.

Should all the methods outlined for recovering the lost bailer fail, then about the only move remaining is to run in the drilling tools and drill it up. Those unacquainted with the details of drilling practice frequently express surprise on learning that when iron or steel tools cannot be recovered, it does not necessarily mean the abandonment of the hole. While such is more apt to be the case with rotary wells than not, the cable tools find comparatively little difficulty in either drilling through metal pieces

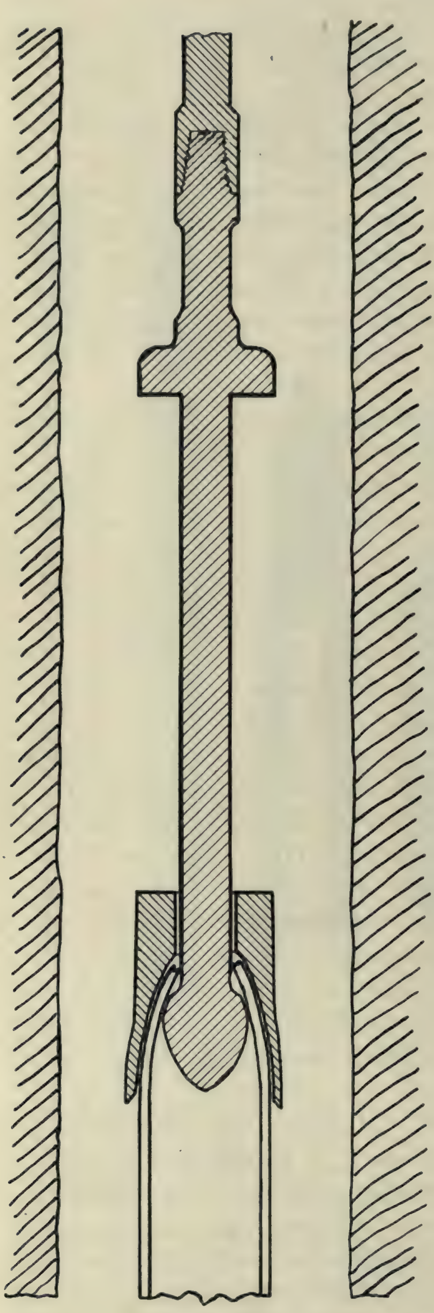


Fig. 175. BELL-SOCKET GRASPING TOP OF BAILER

of quite fair size or in side-tracking these, i.e., pushing them off into the side of the hole, where the ground is soft and permits it. In such work the bit is dressed with a chisel-point or other suitable edge and a suction-bailer of the type shown in Figs. 88, 156 and 157 used to withdraw the pieces of iron as they become small enough to be drawn up into the bailer. The work is often tedious, especially if the piece to be drilled is an under-reamer lug or some other such tool made from extra hard steel, but it is far from impracticable and few cable-tool wells are given up by reason of their being plugged by tools, although this does happen occasionally.

When a line has been pulled from the rope-socket, leaving the entire string of drilling tools in the hole, they may be recovered by one of several types of fishing-tools, the most effective of which is the slip-socket (Fig. 176). This consists of a strong body with a lower opening sufficiently large to admit the top of the lost tool. If necessary a bowl of suitable size for guiding the lost tool up to the opening is attached to the lower outer edge. Two slips, usually made part of a U-shaped rein, are placed in it as shown in Fig. 177, with a small piece of wood pressing them against the tapering inside-face of the socket. A wood

block is also driven between the top of the rein and the top of the two outside openings, in order to prevent the slips from rising when the top of the lost tool passes up between them. When it does so, it pushes away the light piece of wood that holds the slips apart, and when the fishing tools are then lifted the slips bind on the lost tool and hold it while it is being withdrawn. The merit of the slip-socket lies in its simplicity, as well as in the fact that as the pull necessary to dislodge the lost tools becomes greater, the hold of the slips on it increases.

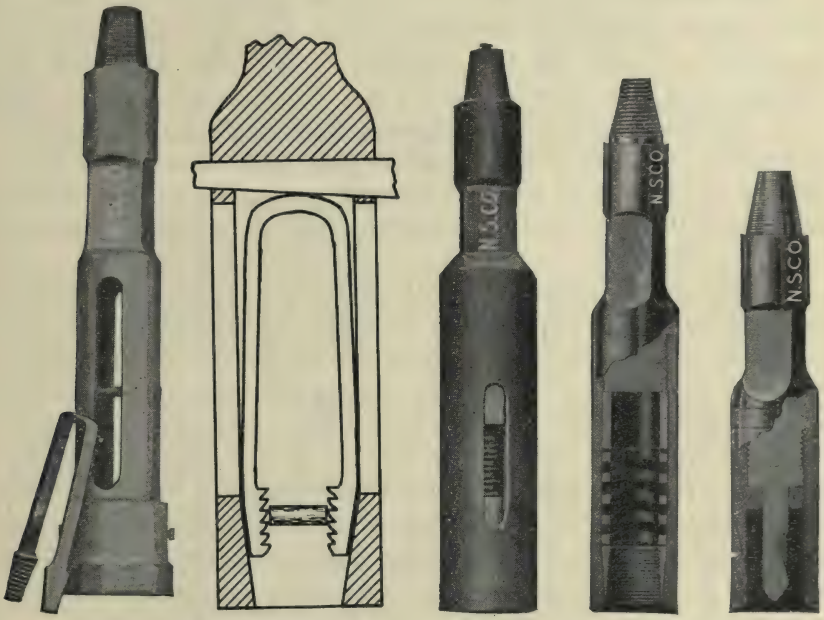


Fig. 176. Fig. 177. Fig. 178. Fig. 179 Fig. 180.

Fig. 176—SLIP-SOCKET WITH BOWL. Fig. 177—SLIP-SOCKET READY FOR USE. Fig. 178—COMBINATION-SOCKET WITH SIDE OPENING. Fig. 179—COMBINATION-SOCKET SHOWN IN SECTION. Fig. 180—TONGUE-SOCKET.

The combination-socket (Figs. 178 and 179) accomplishes the same class of work as the slip-socket, and has even greater strength. It differs in construction from it in having either three or four slips, filling a complete circle on the inside and held down by a coil spring instead of being part of a rein. The larger number of slips permits the lost tool to be grasped more fully, and, as in the slip-socket, the hold of the slips increases with the strength of the pull applied. When using the combination-socket, however,

the exact size of the body to be caught must be known, because of the close fit of the slips, while a considerable range of sizes may be caught with the same slips in a slip-socket. For this reason, when doubt exists as to the size of the tool to be caught it is preferable to use the latter. A further advantage of the slip-socket is that when the lost tools have been pulled from the hole, the rein-slips are much more easily disengaged from their hold than are the slips of the combination-socket.

These sockets are both of the bulldog type, i.e., when they have once taken hold of the lost tool they are not easily released. However, in many cases this may be done, when it has been found impossible to move the lost tool and it is desired to release the fishing-string, by what is known as 'jarring both ways.' The walking-beam is given such a stroke that a jar is applied at the contact of the slips with the lost tool on both the up and down-strokes of the fishing-string, eventually either pulling the socket free from the lost tool or smashing one of the slips, thereby loosening the hold.

When this does not succeed in loosening the fishing-tools and it is considered advisable to withdraw the drilling line, leaving the tools in the hole, the line may be cut by one of the several forms of rope-knives. These are run into the hole on the end of the sand-line, and are simple affairs that consist essentially of a frame, surrounding the line to be cut, and a strong chopping-blade. When the frame has been lowered until the tool rests on the rope-socket of the fishing-string the blade is driven into the line by raising and lowering the sand-line, which drops a metal block on the blade, forcing it diagonally across the drilling-line.

A tool used especially when the drilling-line has pulled completely out of the rope-socket, instead of having broken off at the top of it, is the tongue-socket (Fig. 180), containing a mandrel with slip to run into the opening from which the wire-line has escaped, and a slip inside the main body of the tool for grasping the neck of the socket.

Occasionally one of the joints between the tools in a drilling-string may become unscrewed, leaving the pin of a stem, sinker or set of jars pointing up. In such a case either the combination or slip-socket may be run, unless the body of the tools occupies so much of the space inside the casing that no room remains for the socket to pass over and grasp it. 'Pin-slips' to be used in a combination-socket are made for such a condition, with an inside thread

Fig. 181. MILLING TOOL

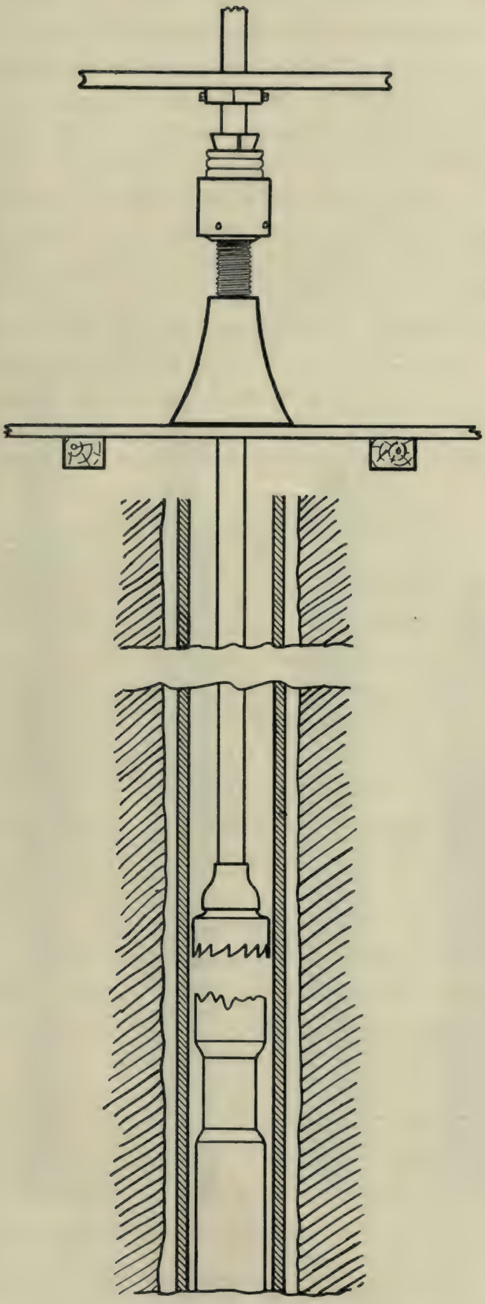


Fig. 182. MILLING TOOL

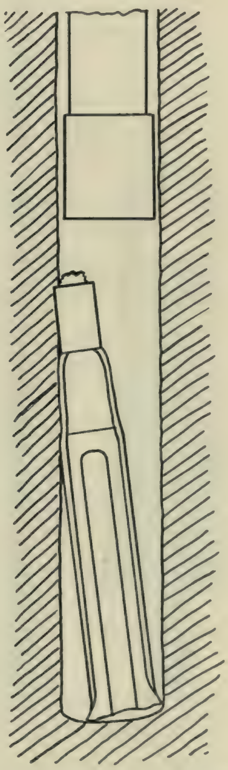


Fig. 183. TOP OF LOST BIT BURIED IN SIDE OF HOLE

conforming exactly to the threads on the pin of the lost tools. When the socket is lowered, the slips fall around the threads on the pin, meshing with these, and hold it while the tools are pulled out. This method is not applicable when the tools are lodged so tightly that they must be jarred before they become free to move.

When the pin-slips will not pull the tools, or the latter have broken at a point where they occupy the entire inside of the casing, it is necessary to cut away an outside portion of the top of the lost tools with a milling tool (Fig. 181). This is run in on tubing, which is suspended from the surface on a specially-constructed jack that holds it as casing is held by a spider and slips, and at the same time permits it to turn readily on a set of rollers. The tubing is turned by a large wheel driven by power, and is gradually lowered by means of the jack as fast as the exterior of the lost tool becomes milled, until a sufficiently long pin has been cut to permit an ordinary socket to grasp it (Fig. 182).

The points that become weakened and break most frequently in a string of drilling-tools are at the joint of the drilling-bit with the stem and directly above this a few inches, where the box of the stem is welded to the stem proper. Breaks of this kind are liable to cause considerable difficulty when the top of the lost tool has become burred and damaged by the subsequent blows delivered before the accident is detected, and also because the bit, or box-end of the stem if the break occurred at that point, is below the bottom of the casing and tends to fall off to one side of the hole (Fig. 183). For this reason it is preferable to use as long bits as possible, many operators never running them when they are worn down to a length of 4 ft. If the bit fortunately remains erect it may be recovered with a slip or combination-socket, provided the top has not been deformed by the pounding to such an extent that it will not pass up inside the slips. If this has happened, a side-rasp (Fig. 184), or two-wing rasp (Fig. 185) must be swung up and down on the end of the fishing-string until the irregularities have been milled away.

When the top of the bit leans to one side of the hole so that the fishing-tools cannot be passed over it, the task becomes more difficult, as it must be brought to a vertical position by drilling around it either with a spud (Fig. 186) or with a hollow reamer (Fig. 187). These bring it to the centre of the hole and at the same time they scrape in cavings from the side which hold it in place. Of the two tools, the hollow reamer, which is really a double-spud, is much the more effective, as its two prongs spring out to a wide sweep

when they have passed below the casing shoe, and if the top of the lost tool has not become too deeply imbedded in the formation alongside it they work it back to the centre of the hole.

If these attempts fail, it may be found possible to drill a hole with the drilling-tools off to the side and below the lost tool, into

Fig. 184 Fig. 185. Fig. 186. Fig. 187. Fig. 188. Fig. 189.

Fig. 184—SIDE RASP. Fig. 185—TWO-WING RASP. Fig. 186—SPUD. Fig. 187—HOLLOW REAMER. Fig. 188—BALL-BEARING JAR KNOCKER. Fig. 189—KESSELMAN CASING-BOWL WITH SLIPS TO RUN ON CASING.

which with a little maneuvering it may be made to fall and then be in a position to be grasped. Another tool used for bringing a lost bit to the centre is the wall-hook, consisting of a long bar bent to a semicircle at the bottom and given a wide sweep so that when run in on tubing or a manila cable it swings the top of the lost tool back to the centre.

When all the attempts outlined above have failed, the plan of shooting the bit off into the neighboring formation is tried. Either liquid nitro-glycerine or 60% dynamite in sticks is inserted in the hole in a sheet-metal tube run into the hole on the end of the sand-line. The tube is made the same length as the bit in order that the force of the shot will apply equally at all points and not drive one end into the formation and leave the other end protruding into the hole. Instead of one electric detonating-cap several are used, to insure an explosion, and the sand-line, with an insulated wire fastened to it at intervals of 50 or 75 ft., completes the electric circuit. Before the shot is fired the casing is pulled up to from 50 to 100 ft. from bottom.

A simple, but more dangerous, method is that of firing with a fuse. The dynamite is inserted in the hole in a water-tight tube on the end of the sand-line. The fuse is lit at the surface and the charge promptly lowered; and while this method is usually successful, especially with shallow holes that allow ample time for the charge to reach the bottom, yet occasionally a premature explosion occurs. The inevitable result is a wreck of the casing opposite the point of explosion, and the hazard is not warranted if the electrical appliances for the first method can be obtained.

Among other fishing-tools employed for recovering lost tools is the 'jar-knocker' (Fig. 188), devised for loosening drilling-tools that are being run without jars, usually with a manila cable, and have become imbedded at the bottom of the hole so that a pull with the drilling-cable does not release them. It is from 8 to 24 ft. long and is run into the hole on the end of the sand-line, with its lower portion around the drilling-cable. As heavy a pull is taken on the cable as it will safely stand and the jar-knocker is dropped onto the rope-socket of the tools a number of times from a distance of 20 or 30 ft., by raising and lowering the sand-line. The jar of this contact, in conjunction with the strain on the cable, soon loosens the tools. The jar-knocker is also used for loosening the two ends of a set of jars that have become locked and do not move freely.

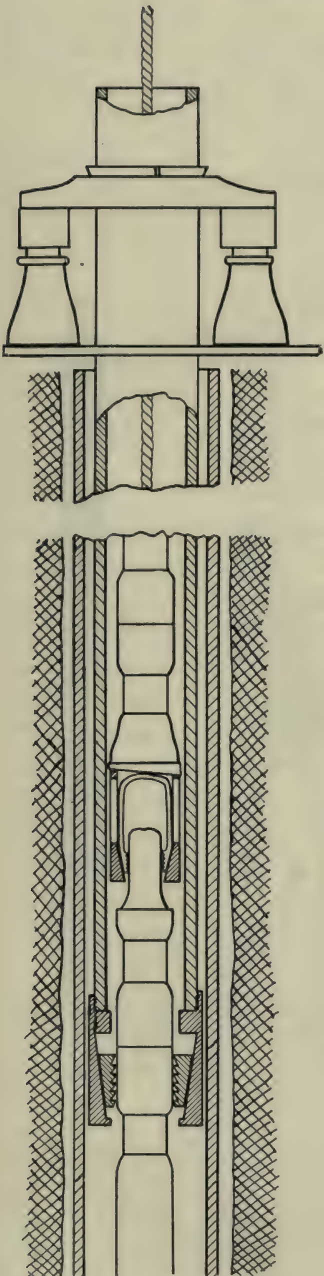


Fig. 190.
LOOSENING TIGHTLY LODGED TOOLS BY MEANS OF BOWL AND SLIPS ON CASING

A feature in connection with the problems of loosening either tools or casing that are lodged tightly in the hole is the fact that the jar applied through the motion of the walking-beam is not as great as might be imagined from observing the sweep of the beam. This is due to the stretch in the line between it and the fishing-tools. For this reason, any method by which a strain may be placed on the tools or casing to be loosened, as the one just illustrated of pulling the drilling-line taut and then jarring with a separate tool, is more likely to be productive of results than is the simple jarring alone.

This principle, of the application of both a pull and a jar, is employed in the casing-bowl method for dislodging tools, wherein the tools are grasped first by a bowl and set of inside slips (Fig. 189), run into the hole on the end of a string of casing (Fig. 190). The casing is held at the surface by a spider and slips, supported by either hydraulic or screw-jacks, and the spider and pipe are raised by the jacks (Fig. 191) until the strain on the casing is as great as may safely be applied without danger of parting the pipe. A socket and string of fishing-tools is then run down inside the pipe until the neck of the rope-socket on the lost tools is grasped, and jarring is then commenced. As the tools gradually become loosened by the upward jarring, the pipe and bowl are raised by the jacks so as to maintain a pulling strain on the lost tools, thus gaining the full effective value of the jarring until the tools are entirely free and may be pulled out. An adaptation of this method is shown in Fig. 192. A shoe or bowl with a beveled inside

surface, is first run in on the end of the casing. A slip-socket is then lowered until it grasps the lost tool, and the casing raised until the beveled surface meets the bottom of the socket, thus applying both the pull of the casing and the jar of the walking-beam to the socket.

The horn-socket (Fig. 193) is a tool with a taper opening for going over a lost tool and taking a friction-hold by which it is held while being pulled out. It is used chiefly for small tools

Fig. 191.
DUFF-BETHLEHEM HYDRAULIC JACK

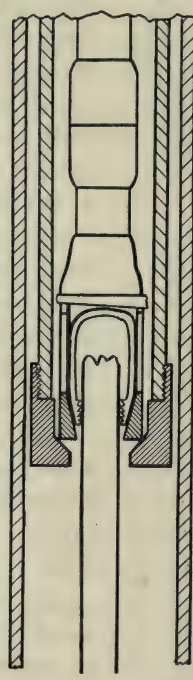


Fig. 192.
BOWL PULLING UP ON SLIP-SOCKET

Fig. 193.
HORN-SOCKET

that are quite loose in the hole, such as bits, working-barrels in pumping-wells, and under-reamer lugs that have broken or become lost from the reamer. The latter are particularly elusive pieces of metal, their shape and small size rendering their capture difficult and their hardness making it almost impossible to drill them up. At times they may be pushed off into the side of the hole, but the movement of casing usually dislodges them and they

drop back to the bottom again. A basket similar to that shown in Fig. 194 may occasionally be made to catch a lost lug, by running it in on the drilling-tools and churning until the wickers have closed in about it. A great variety of special tools of one kind and another has been devised for recovering these lugs, but as yet nothing that may be considered thoroughly satisfactory has been developed.

In connection with the problem of recovering lugs, as well as many other of the small tools that resist capture, the possible application of some form of a magnet appears to offer a wide and inviting field. Considerable experimental work along this line has been carried on, but the technical difficulties seem to have been too great for successful results, although the principle is sound and would be of great value if it could be applied under the peculiar conditions of pressure at the bottom of a deep hole filled with water and in the presence of bodies of casing, which have themselves in nearly all cases become highly magnetized.

Fishing for Casing. Among the accidents that may hinder the progress of drilling a well, and involve no small expense as well as loss of time, are the mishaps that occur to the casing, especially in those fields where the sides of the holes cave badly and give rise to the constant danger of cavings falling in and binding the pipe. The extent to which conditions of this nature may endanger the casing depends entirely upon the ground. Some formations 'stand up' and are so compact and closely cemented that no dirt falls in, while others disintegrate rapidly and unless the pipe is moved up and down at frequent intervals, so that the materials fall to the bottom of the hole, it soon becomes bound with so much loosened dirt that it resists all efforts to move it.

Frequently, when casing has become 'frozen' in this way and cannot be pulled up, it may be driven down for a few feet and then pulled back to its original position, driven again and so worked up and down until it is loosened. The driving is accomplished by inserting a drive-head (Fig. 94) in the coupling at the top of the string of casing and striking this with heavy clamps attached to the drilling-tools, raising and lowering the tools either by direct drive from the bull-wheel shaft or with the jerk-line and spudding-shoe. Another resource that may be tried is that of bailing the water from the inside of the pipe, causing the pressure of the water on the outside, between the pipe and the wall of the hole, to tend to force the sands that are binding the pipe down to

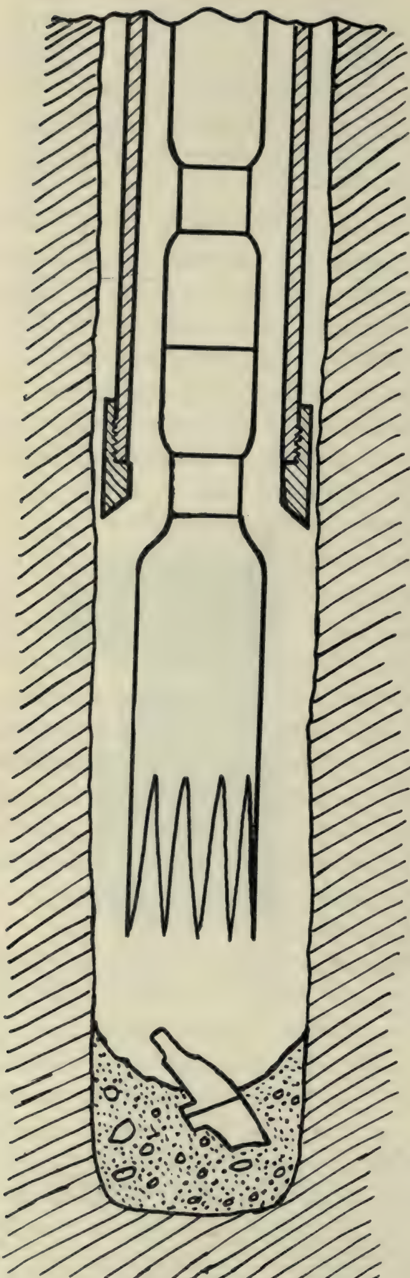


Fig. 194. BASKET-TOOL FOR CAPTURING UNDER-REAMER LUG

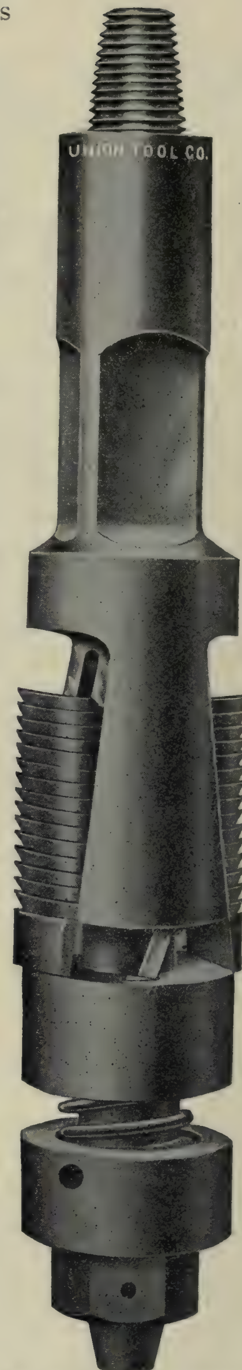


Fig. 195. FOX TWO-SLIP TRIP CASING-SPEAR

the bottom of the hole. In either of these methods, precautions must be taken to prevent the sudden descent of the pipe for any considerable distance after it has become free, because of the danger of its bending or telescoping. The usual device is a wire sling suspended from the casing-hook and attached either to the ends of the spider or to each of the two links of an ordinary elevator.

Frequently it is necessary to apply more forcible measures before the casing may be dislodged, and for this work spears that take hold of the pipe, and by means of which it may be jarred, are universally used. Usually they are run into the hole, on a drilling-line and string of tools, until the desired depth is reached; they are then pulled up till the slips engage with the inside of the pipe and jarred until the pipe is moved.

The most simple form of spear for this purpose is the common bulldog-spear (Fig. 172), which is rarely used, however, because it may not be pulled up in the pipe after the slips have once taken hold. Many improved patterns, such as those shown in Figs. 195 and 196, are so constructed that when it is desired to free the spear and withdraw it from the pipe, a downward jar of the tools causes the slips to become disengaged and fall into a recess in the body of the spear, where they remain while it is being pulled out. A dozen or more styles of 'trip' spears, as these are known, are made for service of this kind, some with two and others with four slips, and all work along the same lines of being lowered to the desired point and then raised, at which time the slips engage with the pipe. When lowered a second time, the slips trip back into a recess and remain there, and the spear must be pulled from the hole and the slips 'set' again before they can be made to grasp the pipe. The most common type is made so that the slips grasp the pipe for an upward pull, and is known as the 'jar-up' spear. For jarring down on pipe the oblique plane holding the slips is reversed.

Often the point at which the pipe is bound will be found to be at the casing-shoe, which, by reason of its slightly greater diameter, is holding back cavings that would otherwise pass to the bottom of the hole. Or it may be that the shoe has been lowered into an opening just small enough to bind it. In such cases a few taps with a casing spear usually succeed in knocking it loose. At other times the friction may be so great that jarring must be continued for several hours, or days, before the pipe starts to move.

Fig. 196. FOX FOUR-SLIP TRIP CASING-SPEAR

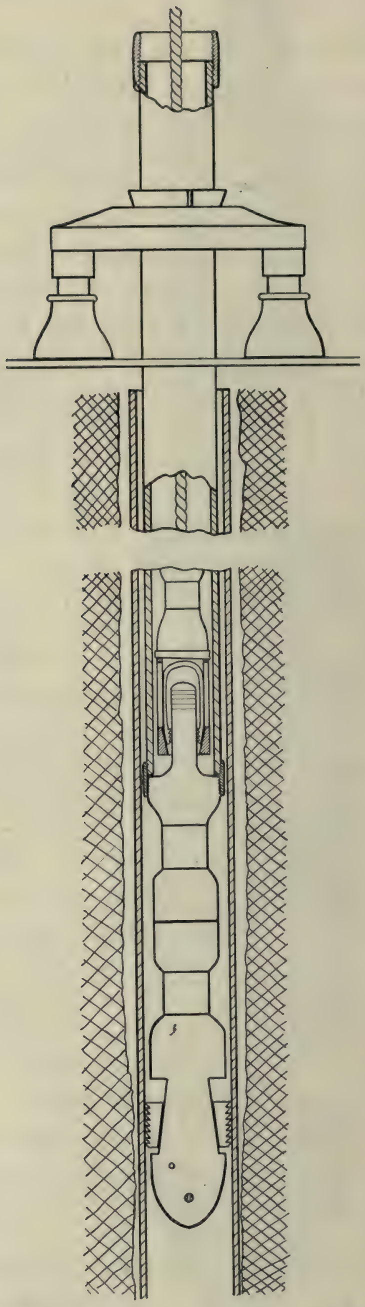


Fig. 197. CASING-SUB AND AUXILIARY STRING FOR DISLODGING FROZEN CASING

When the casing resists the usual attempts with a spear to free it, the plan illustrated in Fig. 197 is often found successful. As in the casing-bowl method of loosening tools by the aid of an auxiliary string of pipe, the casing-spear is run into the hole on the end of a second string of casing, that will pass readily inside of the frozen string. The spear is attached to the pipe by a 'casing-sub,' which has an outside thread for screwing into a coupling of the pipe on which it is run; its lower portion is a box for fastening it to the casing-spear and the upper end is a mandrel, similar in shape to the neck of a rope-socket. When the spear has been lowered to the point where the cavings are binding the casing, it is made to take hold of the casing and as great a pull is taken on the auxiliary string of pipe, with a set of jacks, as is safe. A socket and string of fishing-tools are then run down on the drilling-line, inside the second string of pipe, the mandrel of the casing-sub is seized and jarring is commenced. A second set of jacks may be used to pull directly on the frozen string of casing, and this with the pull of the pipe on the spear and the jarring applied with the tools and socket combine to place a terrific force on the frozen casing. If this fails, either to loosen the pipe or to part it, some new line of attack must be followed.

At this point several methods of procedure may be followed, depending largely on local conditions. The simplest is the abandonment of the frozen casing and the insertion of a smaller sized string. But circumstances may be such that it is considered imperative that the pipe of the size frozen be carried to a greater depth than it had attained at the time it was lost. It then becomes necessary to part the frozen casing at a point above the zone where it is bound tightly, pull out the recovered portion and run it back with a new casing-shoe on the bottom, and drill a new hole off to the side of the portion left remaining in the hole.

In the course of the attempts to loosen it the pipe may have parted, but if it has not done so it may be divided at any point by cutting or dynamiting. Before doing this it is customary to ascertain the point nearest the surface where the binding effect of the caved material ceases. This is learned through the fact that when the spear is jarred at a point opposite where the pipe is bound, the top of the casing at the surface will not move or exhibit any 'vibration' when the hand is placed on it. But when the jarring is applied at a point in the

pipe above the cavings, a noticeable movement of the casing is apparent at each stroke of the walking-beam.

Casing is cut by means of a tool (Fig. 198) holding four small sharp-edged wheels similar to those used in an ordinary hand pipe-cutter. The cutting wheels are each held in a sliding block, all the blocks pointing towards the centre of the body of

Fig. 198. CASING CUTTER

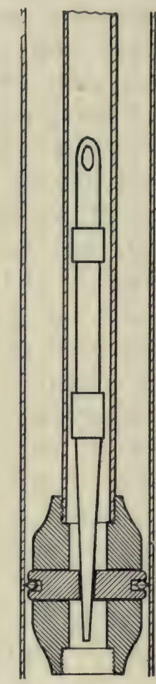


Fig. 199. CASING CUTTER WHEELS ENTERING CASING

Fig. 200. JONES CASING CUTTER

the tool. It is run into the hole on tubing and when the desired depth is reached, a long taper mandrel is lowered inside the tubing on the sand-line. This mandrel enters an opening in the body of the cutting-tool and pushes out the blocks holding the cutter wheels (Fig. 199). The tubing is then turned and the mandrel gradually forces the cutter wheels out into the body of the casing. Another type of cutter (Fig. 200) is so constructed

that the taper mandrel is part of the tool and when it has been lowered on tubing to the point at which the casing is to be cut, a short reverse turn of the tubing releases the mandrel, which then pushes out the cutter-wheel blocks as it is raised by a pull on the tubing. When this cutter is used, the tubing is suspended from the temper-screw by which it is pulled up at the same time that it is being turned.

Sometimes considerable difficulty is encountered in endeavoring to cut casing, and, to expedite matters, it may be decided to shoot it. The general methods outlined in the discussion of side-tracking lost bits are employed for tearing the casing apart, or the shell containing the dynamite may be lowered on the end of a string of tubing, screwed up tightly so that it allows no water leakages, and exploded by dropping down on it, through the tubing, a short piece of pipe containing two or three sticks of dynamite with caps and fuses. Whenever possible, however, it is advisable not to use any but the electric method for detonating, as the liability of a premature explosion with other methods involves risks of injury to the men and damage to the casing.

A third method of parting pipe is that of ripping it until it is so weakened that it may be pulled apart. The chief use of the tool shown in Fig. 201 is for perforating casing to admit oil, as shown by the series of sketches, but it serves equally well as a ripper when used with a suitable knife. The body contains a slotted opening for the passage of a bar up and down beneath a knife, which swings on a pin. Screwed into the lower end of the bar is a long rod or plunger, serving as a guide for a frame with two or more expanding wings of spring-steel that bear against the inside of the casing. When lowered in the hole, on tubing with a set of jars between the tubing and the perforator, this frame is placed above a small spring-key, situated near the lower end of the plunger, and the frame is pushed ahead of the body of the perforator while it is being lowered. When the proper depth has been reached and the tools and perforator are pulled up a few feet, the bar and plunger are drawn up by the body of the perforator, leaving the expanding wings motionless until the frame has slipped down over the spring-key. The key and nut at the end of the plunger now prevent the frame from further movement on the plunger, and when the tubing and perforator are again lowered, the springs bearing against the side of the casing hold the frame quiet and the bar at the upper end of the plunger pushes up the loose end of the knife. The point first pierces

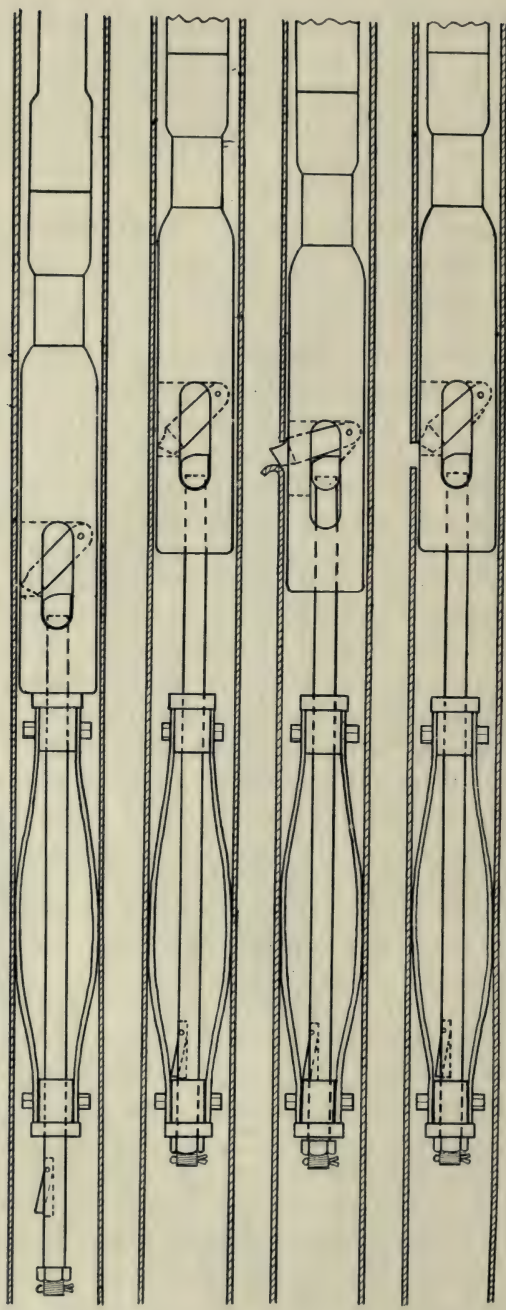


Fig. 201. CYCLE OF OPERATIONS WITH SINGLE-KNIFE PERFORATOR

the pipe and as the body of the perforator is lowered further, the knife comes to a horizontal position, punching a rectangular hole and holding the tools and tubing from further movement downward by the square shoulder on its lower side which will not cut down through the pipe. The tools are then raised to the point at which another hole is to be cut and the operation repeated.

Knives for punching a number of apertures, through which oil may gain admittance to the inside of the casing, are so made that they cut a rectangular hole of the desired size. Those for ripping the pipe or a coupling have a cutting edge similar to the rounded blade of an ordinary knife (b Fig. 202) so that when the knife has once made an incision it continues to rip the pipe as long as forced down by the weight of the tubing, or the jarring of the tools.

It is not uncommon for casing to part of its own accord at some point in the hole. This may result from the great strain of the weight of a long string, from the pull applied when trying to loosen a frozen string, or because of defective threads. Pipe rarely

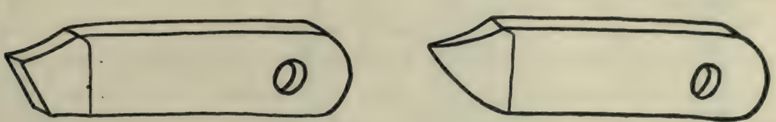


Fig. 202. (a) PERFORATING KNIFE (b) RIPPING KNIFE

parts at the middle of a joint, the threaded portion directly where it enters the coupling appearing to be the most liable to break. Some styles of elevators, particularly when they have become worn, tend to pinch the casing directly below the coupling and weaken the bond between the pipe and the coupling at the thread. Such an injury to the pipe may not be noticeable at the time it is inserted and the weakened joint may be several hundred feet from the surface before an especially great strain is placed on the casing, causing it to part at this point.

The remedy in these cases is to withdraw the upper portion of the string and place on the bottom of it a steel die-nipple (Fig. 203) by means of which a thread may be cut on the top of the lost portion. The threaded parts of a die-nipple are usually 5 or 6 in. in length, with a slight taper and are grooved or fluted transversely to the direction of the thread in order to permit the steel cuttings to escape.

When the break occurs at the lower end of a coupling, all that is necessary is to run in the die-nipple and turn the casing until a

sufficient thread has been cut on the outside of the lost pipe to insure a bond with the threads of the die-nipple. If the break is at the top of a coupling, leaving it in the hole, it may be that the outside threaded end of the die-nipple can be screwed into it; but unless the coupling is unusually long, enough threads cannot be cut to secure a tight hold and it is a more common practice to cut the pipe with a casing-cutter a short distance below the coupling and bring the loose piece holding the coupling out with the cutter when it is withdrawn. This leaves a cleaned end of the pipe exposed, over which the inside threaded end of the die-nipple may be screwed.

Some operators prefer to use, instead of a die-nipple, a casing-bowl. The bowl, especially when equipped with two sets of slips (Fig. 173), supplies a much stronger hold on the lost pipe, and effects a saving in time, since the pipe need not be withdrawn for the removal of the bowl unless it is the string that is to exclude water from the oil-sand. When a die-nipple has been used to join the two ends, it is safer to pull the pipe and remove the nipple and defective joint.

Another accident to which casing is subject is that of collapsing, either because of the pressure exerted against it by the column of water on the outside when it has been bailed dry, or through a rock or boulder falling in and grinding against the side. In the latter case, as the well is deepened and the pipe lowered the boulder becomes wedged between the wall of the hole and the pipe, directly below a coupling, forcing a portion of the pipe inward so that the tools or bailer are prevented from passing through at this point. Under ordinary circumstances the pipe may be pulled from the well and the damaged joint removed from the string. But when the string of casing has been landed and cannot be withdrawn, or the depression is only a slight one, a swage (Fig. 204) is run in on the drilling-tools and worked up and down until it has forced back the pipe to its original position. Water-courses are provided by fluted channels diagonally along the side.

Another form of swage contains a hole bored diagonally from the bottom to a point on the side near the pin. Such a tool is necessary when the drilling-tools have become imprisoned by a collapse in the pipe that has occurred while the tools were in the hole. If it is deemed inadvisable to cut the drilling-line above the weak place in the pipe, a new line is strung and the swage and a second string of tools are lowered in the hole, the swage passing down around the first line by sliding it through the opening. In

this way the lost line does not interfere with the action of the swage. A third form of swage contains a series of rollers at the circle of its widest diameter, for rendering the swaging action more effective.

In the fields where the strata are steeply inclined, the direction of the holes is frequently thrown off from the vertical by reason of the constant deflection of the drilling-tools in the direction of the dip. Such a condition may result in one or two joints of pipe being broken off when the casing is lowered to where the hole swerves. The pieces are usually quite loose in the

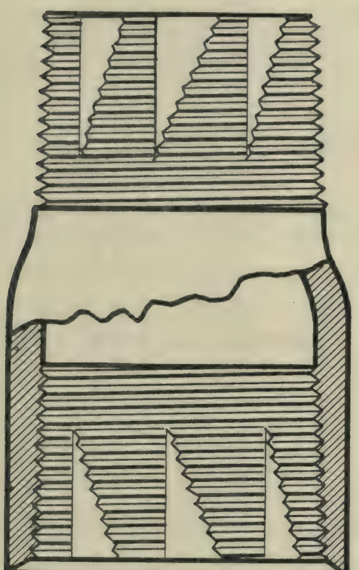


Fig. 203. DIE-NIPPLE

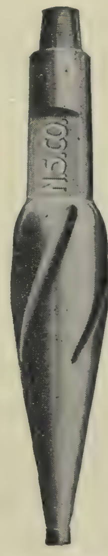


Fig. 204. SWAGE WITH FLUTED WATER-COURSE

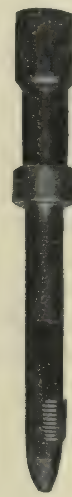


Fig. 205. BULLDOG TUBING-SPEAR

hole and may be recovered with a spear or a bell-socket. In fact, it is said that the latter was first used for jobs of this kind before its wider application for fishing bailers and broken tubing was developed.

Accidents to Producing Wells. The accidents that befall producing-wells, while of rather frequent occurrence, are not liable to be of a serious nature, and the remedies are usually simple. Aside from the unscrewing of sucker-rods, parting of the tubing is probably the most common mishap. This may result from carelessness while withdrawing or inserting it, from defective

threads weakened by long wear, or from what is known as the 'back lash' of sucker-rods, caused by the rods parting at the time a strain has been placed on them when trying to loosen a plunger that is 'sanded up' in the working barrel.

If the tubing drops only a short distance, it will usually remain intact and may be recovered with a bulldog tubing-spear (Fig. 205). In producing-wells, the fishing-tools are customarily run on tubing, instead of a drilling-line and string of fishing-tools, since the latter has usually been removed for use elsewhere. However, a precaution that should always be followed is that of inserting a set of jars between the tubing and the spear. The need for this arises from the fact that the lost tubing may be wedged so that in applying a direct pull on it sufficiently strong to pull up the lost material, there will be considerable danger of parting the tubing at a new point above the spear. With the jars placed between the tubing and the spear, a few upward bumps may be applied and the lost pipe dislodged.

When the size of the casing is enough greater than that of the lost tubing inside of it so that difficulty may be experienced in getting the spear to enter the tubing, a hood or bowl is attached to the spear for the purpose of guiding the tubing up over the latter, as in Fig. 206. This figure illustrates also another type of the same style of spear, found to be more convenient where several different sizes of tubing are in use on the same property. Instead of a solid body throughout, it is so constructed that any one of the different bars or mandrels with slips for grasping the various sizes of tubing may be screwed into the body.

When the lost tubing cannot be pulled readily but must be jarred before it becomes free, the jarring of the spear often splits the tubing until the slips reach the end of the joint at which, if a collar has remained at the top of the lost pipe, the slips become lodged and take hold while it is pulled out. If no collar is at the top of the uppermost joint in a lost string that is being split, a spear-mandrel about 25 ft. in length is used, permitting the slips to pass through the top joint and grasp the second joint below the collar that connects it with the first joint.

The behavior of tubing when dropped seems to be very erratic. At times it falls for a considerable distance without suffering any material injury, and in other cases, when dropped possibly only a few feet, assumes a spiral shape or breaks at a number of points. In such instances the upper portions become wedged with the lower, two or more pieces will be flattened against each other, and

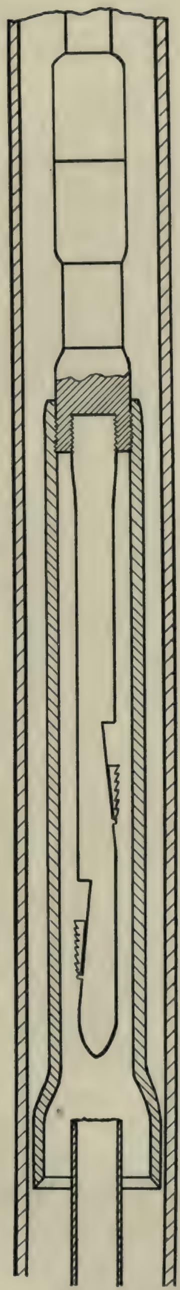


Fig. 206. TUBING-SPEAR WITH BOWL

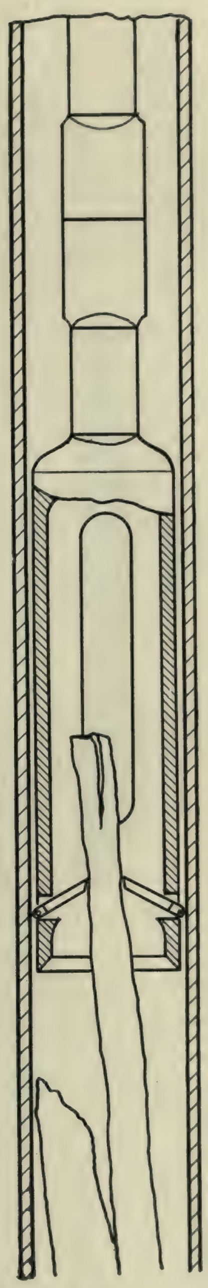


Fig. 207. TUBING OVERSHOT

the difficulty of its recovery is greatly increased because the pipe is no longer in a single string and the flattened openings prevent the ready admission of the ordinary spears.

When such an accident has occurred, it is advisable to expedite the fishing by installing a drilling-line and string of tools, which may be run in and out of the hole faster than can be done with tubing and permit more effective jarring in the endeavor to loosen pieces of pipe that resist an ordinary pull. Deformation of the lost tubing renders it imperative in nearly all such cases that the attempts to fish it out be made with forms of overshot-tools, that grasp and hold the exterior of the pipe. The impression-block is also a very necessary help, as it must be run after each piece of pipe has been pulled in order to show the shape of the next piece that is to be caught. Much ingenuity is shown in designing special tools with which to recover such material, the bell-socket (Figs. 174 and 175), rotary over-shots (Figs. 212, 213 and 214) and casing-bowls all being called into requisition and adapted at one time or another for work of this class.

Fig. 207 illustrates a simple but remarkably useful tool for grasping the outside of crooked and odd-shaped pieces of pipe. It is made from the body of an ordinary combination-socket, with the spring and slips removed, and slotted near the bottom so that a 'dog' of any desired size or shape may swing on a pin-hinge placed in a recess on the outside edge. The 'dog,' or 'dogs,' if provision is made for two to swing opposite each other, is free to move exactly as does the flapper-bottom of a flat-bottom bailer, and when in a horizontal position it rests on a shoulder turned near the bottom. When the impression-block has indicated the size and shape of the projection to be grasped, a suitable dog is made (Fig. 208), so shaped that when the socket is lowered over the lost pipe the dog swings upward. Then when the socket is raised, the dog grips the pipe with a friction-hold while it is being withdrawn.

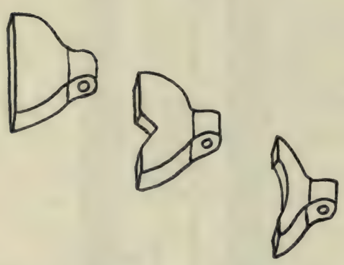


Fig. 208. DOGS FOR TUBING-SOCKET

Another tool occasionally used is a bowl with a long, tapered, inside thread, similar to that in a die-nipple, by which it is made to screw over and cling to the lost tubing. The cutting-thread, and thread of the pipe on which the tool is run, are made left-hand,

so that if the lost string is wedged tightly the bowl not only grasps the top piece but also unscrews such a portion of the tubing as will turn.

The most common accident to sucker-rods, in pumping-wells, is that of unscrewing at the joint of a pin and box. They usually may be screwed together again without having to pull them from the well. When the string is parted by a rod breaking, the lost portion is recovered either with a sucker-rod socket or with a 'mouse-trap.' Both tools are run inside the tubing on the rods; the former (Fig. 209) is constructed like the combination-socket used for fishing lost tools, and is the more effective of the two unless the top of the rods has become burred so that the slips will not pass over it. The mouse-trap (Fig. 210) is made from a piece of heavy pipe, small enough in diameter to go inside the tubing. In its simplest form it has a fork-shaped hinge near the bottom, which falls in around the pipe underneath the sucker-rod box and holds it while the rods are pulled out. Another form contains a slip by which a friction-hold may be secured at any point on a rod.

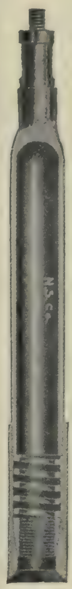


Fig. 209. COMBINATION SUCKER-ROD SOCKET

Rotary Fishing Tools. When drilling is being carried on by the rotary method the variety of accidents that may happen is smaller than when cable tools are used, since the drill-stem and bit are the only equipment run into the hole. Such difficulties as occur with these are generally of minor consequence, but when troubles do develop they appear to lead, more often than with cable-tool wells, to the abandonment of the hole. If the job reaches such a stage that the fishing-tools are run in and out of the hole frequently, the work progresses much more slowly than with cable-tool wells, where the tools are run on a line.

The most common difficulty results from the twisting and separating of the drill-stem, usually near the bottom where the

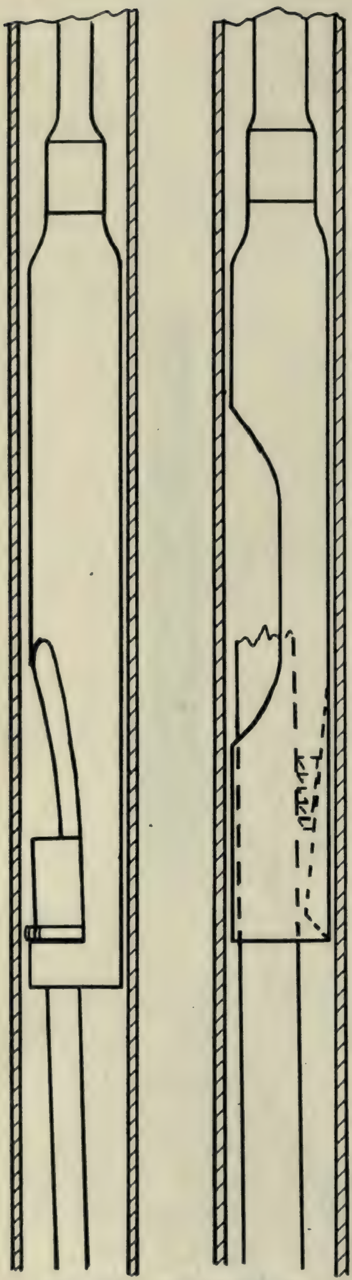


Fig. 210. MOUSE-TRAPS
With check-valve With slips

Fig. 211. WASH-DOWN SPEAR

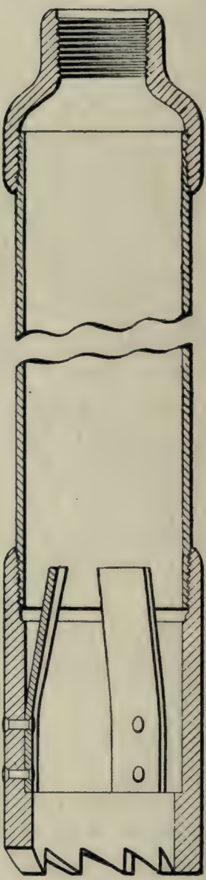


Fig. 212. SPRING OVERSHOT

torsional strain is greatest. 'Twist-offs' are recovered either by spears that grasp the inside of the pipe with slips, or with various styles of overshots that run over it and grip it on the outside, usually directly underneath a collar. The usual type of spear (Fig. 211) has openings through which the circulating fluid is

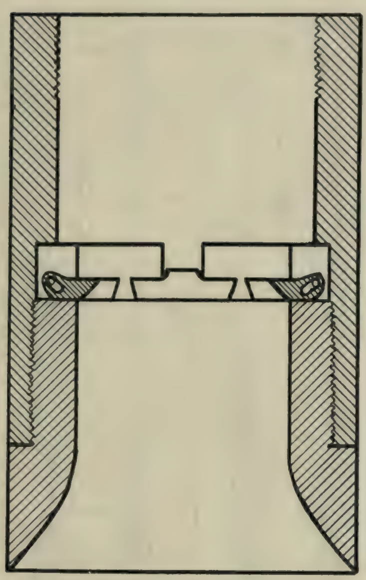


Fig. 213. ROTARY OVERSHOT WITH SWINGING DOGS

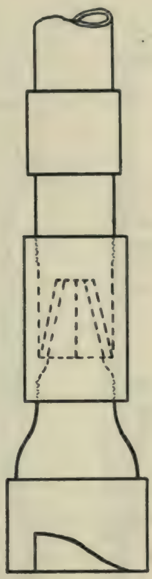


Fig. 214. SNOW-KIDD ROTARY OVERSHOT

pumped as with the rotary bit, and has a single circular slip that grasps the full body of the drill-pipe on the inside. A short diamond-shaped guide is inserted in the bottom for steering the spear into the pipe, but if the top of the pipe has fallen off to the side of the hole, considerable patience is often required before the spear may be made to go into it. In such a case an off-set joint is usually placed in the drill-pipe on which the spear is run, directly above the spear, so that it is swung off to the side of the hole and passes more readily into the lost pipe.

The overshot most commonly used is made with a set of springs on the inside (Fig. 212) which permit the tool to pass down over

the lost pipe, but which, when pulled up, clasp it underneath a collar. Another form is that shown in Fig. 213. This contains three or four 'dogs' on a pin-hinge, which swing up when going down over the couplings of the lost pipe and fall back to a horizontal position when beneath a coupling so that, when lifted, they pull it up. A third style (Fig. 214) is shown recovering lost pipe in Fig. 215. In this the two slips are heavy solid pieces,

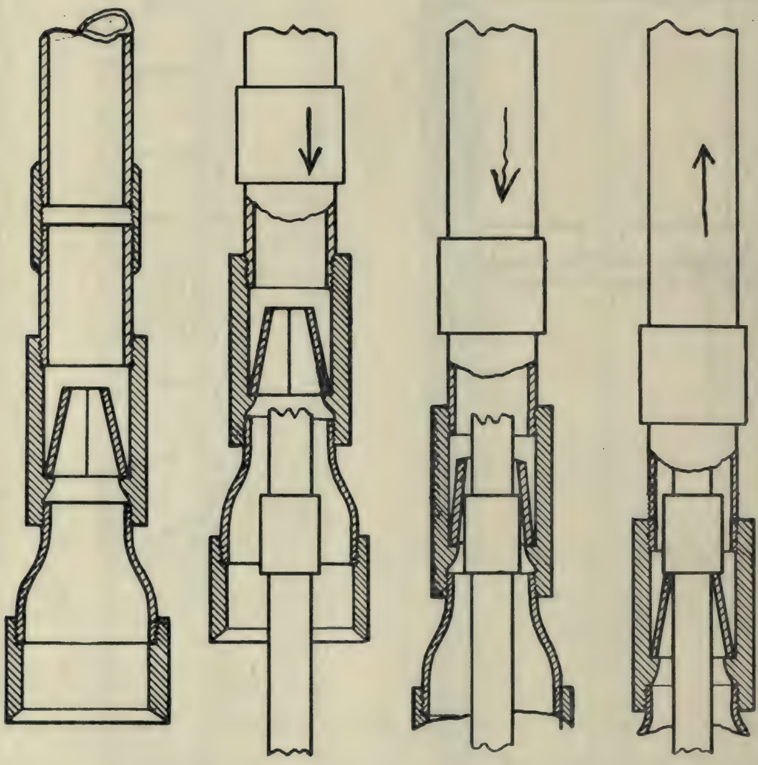


Fig. 215. CYCLE OF OPERATIONS OF SNOW-KIDD ROTARY OVERSHOT

supported on a shoulder in the body of the overshot. They are so made that when placed together their lower edge is a complete circle, while the top edge is not circular but has the inside diameter of the bowl for one axis and the outside diameter of the lost pipe for the other. As the bowl is lowered over a collar of the lost pipe, the tops of the slips are pushed back, but fall in against the pipe as soon as the collar is passed, and when the bowl is

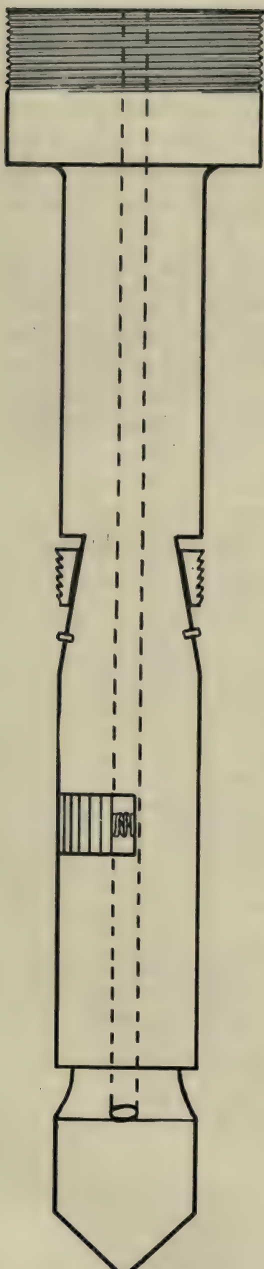


Fig. 216. ROTARY WASH-DOWN SPEAR for Unscrewing Frozen Drill-Pipe

raised, the portions represented by the small axis lodge against the pipe beneath the collar and bear up against it while it is being pulled up. A shoe with an opening cut in one side, as shown, is usually run ahead of the bowl for guiding the lost pipe up inside of it.

A form of accident liable to occur when drilling with the rotary tools and which may develop into serious difficulties, is that which arises from dirt binding the drill-stem, either through the unexpected heaving of sand when a gas-stratum is encountered, or through the sides of the hole caving in. The simplest way out of trouble of this kind is to run an overshot on a string of pipe that is large enough to pass over the lost drill-pipe.. The overshot is preceded by a rotary casing-shoe and the circulating fluid is pumped down inside the larger string, removing the caved material as fast as it is loosened by slowly turning the shoe. In this way the caved ground is cleaned out and when the larger string is withdrawn the overshot pulls the drill-pipe with it. But in many such cases the small space between the lost pipe and the fishing-string, and between the latter and the side of the hole, hinders the free circulation of mud and not infrequently causes the fishing-string itself to become frozen, thus complicating matters still further.

For this reason it is generally considered preferable, although requiring more time, to recover the lost pipe in single joints, by unscrewing them. The fishing string is left-hand-thread pipe and the tool run on the bottom of it is a wash-down spear (Fig. 216), with a circular slip or with two ordinary bulldog tubing-slips. In addition to these, and the opening for the passage of

the circulating fluid, it is equipped with another slip, which is moved horizontally by a spring, the duty of which is to grip the inside of the lost pipe when the fishing-string is turned to the left. When the body of the spear has entered the top of the lost pipe, the fishing-string is turned to the left until one or more joints of the lost pipe have been unscrewed. The fishing-string is then withdrawn, pulling with it, by means of the vertical slips, the unscrewed sections.

If the well is remote from where left-hand pipe may be obtained, the ordinary pipe may be used by boring a hole through the coupling and pipe at each point where the two come together and inserting pins in these openings when the pipe is being run into the hole. The pins thus prevent the pipe from unscrewing when the left-hand turn is given it in unscrewing the lost pipe.

CHAPTER VIII.

ACCOUNTING SYSTEMS.

The oil industry on the Pacific coast is young, consequently much experimenting has been done in the way of accounting systems for oil companies. It is only during the last few years that operators have realized the importance of efficient accounting systems whereby a check can be kept upon operations, and monthly exhibits obtained showing operating results in concise form. Many companies at present have systems burdened with detail, and either a proper answer is not obtained or else the results do not justify the effort. Too often there is a duplication of work at the field and main office. With a properly arranged system the entire details should be handled at the base of operations, which is the field, and information transmitted to the main office in consolidated form so that results are easily obtained and no duplication of work is necessary. This can all be done without effecting control by the main office upon the operations at the field and at the same time it provides for a complete check on the detailed accounting.

The chart of accounts (see folding plate) is a graphic representation of the entire classification of accounts, showing the relation that one account bears to another and of all accounts to the balance sheet. The operations of an oil accounting system may be classified as follows:

(a) Development
(b) Production
(c) Pay Roll
(d) Purchasing and Stores
(e) Teaming
(f) Miscellaneous Departments
(g) Reports
(h) Financial Statements

Development (Drilling). At the end of every twenty-four hours a Drillers Tower Report (Form No. 1) is sent to the field

office with time cards. From the information contained on this report the Daily Drilling Report (Form No. 2) is made out in duplicate, original to main office and duplicate, after being recorded on the Well Log (Form No. 4), is sent to the superintendent of development. It is filed by well number and date.

The well foreman each day makes out the Well Pullers Report (Form No. 3) giving a detailed description of the well-pulling operation of each well. It is sent to the superintendent of development and is filed by well number and date.

WESTERN OIL CO. DRILLERS TOWER REPORT Date, 19 .	
Well No. Property,	Lost Time,
Came on Tower at. Finding	Cause,
Depth Formation,	
Formation changed during my Tower	Material Used,
At, Ft To.	
At, Ft To,	Material taken out,
At, Ft To.	
Samples taken at. Ft	Total Material in Hole,
No Ft made during Tower	
Oil found at, Ft	Went off Tower
Gas found at, Ft	
Water found at, Ft	Driller
Note Particularly each change in Formation and Depth at change	
Well No. Property	Lost Time.
Came on Tower Finding.	Cause,
Depth. Formation,	
Formation changed during my Tower as follows	Material Used,
At. Ft To	
At. Ft To	Material taken out.
At. Ft To	
Samples taken at, Ft	Total Material in Hole
No Ft made during Tower	
Oil found at. Ft	Went off Tower
Gas found at, Ft	
Water found at. Ft	Driller

Form 1. DRILLERS' TOWER REPORT

Production (Pumping). At the end of every twenty-four hours the Daily Report of Wells Pumped (Form No. 5) is made out in duplicate by the pumpers and shows details and conditions regarding pumping. The original is sent to the main office and a duplicate is given to the superintendent of production. After recording on the Recapitulation of Oil Production (Form No. 6) they are filed according to pumping plant and by date.

When oil is delivered to the consumer, Run Ticket (Form No. 7) is made out in triplicate. The original is given to the consumer, a duplicate sent to the main office and a triplicate held in a numeral binder at the field office. Run Tickets are posted to Recapitulation of Oil Production (Form No. 6). The main office upon receipt of duplicate, checks extensions and then posts same to Consumer Statement in duplicate, entering thereon ticket number, quantity and amount.

WESTERN OIL CO.	DAILY DRILLING REPORT	No ______ Well No ______
For 24 Hours ending at ______ M on ______ 19__		

Depth at Last Report Ft.	Casing at Last Report, Ft
Drilled to day Ft	Put in today, Ft
Present Depth Ft	Total now in, Ft
Kind of Casing Used,	Weight per Foot,

Description of Formation Found				
From	To	Ft		
From	To	Ft		
From	To	Ft		
From	To	Ft		
From	To	Ft		
Water-struck at,		Ft in formation of		
Rises in hole to within		Ft from top Kind of Water		
Shut off Water at,		Ft in formation	With	Casing
Weighing	Lbs. per Ft	Cemented at	No of Sacks used	Brand
Oil- struck at,		Ft. in formation of		
Went through oil stratum at,		Into,		
Oil Sand known as,				
Driller - Morning.		Afternoon.		
Tool Dresser - Morning.		Afternoon.		
		Signature,		
Mail Original Report Daily to Main Office, San Francisco.				

Form 2. DAILY DRILLING REPORT

The record of oil in each tank is kept on the Recapitulation of Oil Production (Form No. 6). Postings are made to this form from Daily Report of Wells Pumped (Form No. 5) and Run Tickets (Form No. 7).

Pay-Roll System. The principal divisions of the pay-roll system are:

(a) Hiring.
(b) Time Keeping.
(c) Time Recording.
(d) Discharging.
(e) Paying.

The original record of employment is the Hiring Card (Form No. 8). This form is filled out by foremen for each employee starting to work, and is sent to the pay-roll clerk who makes notation of same on Pay-Roll Record (Form No. 9). It is then placed in a vertical file in numerical order by employee number.

WESTERN OIL COMPANY WELL PULLERS REPORT	
Well No	19
Property	Well No
Rods Pulled	
Length of Tube Pulled	
Length of Tube Replaced	
Original Depth of Well	
Number Feet Filled In	
Depth After Bailing	
Note below, or on back, All repairs made and material used.	
	Foreman

Form. 3. WELL PULLERS' REPORT

Drillers and toolers record their time each day on a Drilling Time Card (Form No. 10) showing their name and number, well

WESTERN OIL COMPANY

Record of Well No. Section No.

General Information		
Depth	Total Oil Formations.	Remarks
Elevation	Gas	
Date began Rigging	Date Began Pumping.	
Date Spudded	Rating.	
Date Finished.	Gravity (After 30 da.)	
	Per Cent Water.	
Drillers.	Tool Dressers.	

Oil Sands				Water Sands			
From	To.	Ft.	Remarks.	From.	To.	Ft.	
							Cement.
							Amount.
							Method.
							Time
							Results
							Cement.
							Amount.
							Method.
							Time.
							Results.

Casing Record								
Brand	No Ft.	Size.	Weight	Thread	Landed	Cut.	Kind of Shoe.	Purpose

Perforation Record									
Date	Size Case	From	To.	Ft.	Rows.	Centers	Holes.	Machine Used.	Perforations.

Heaving Plug.				Adjusters.		
Make.	Material.	Length	Where Set.	Make	Material	Size

Form 4. WELL LOG (*Front*)

number, time and duty engaged in. These cards are dropped in a box kept at boarding houses for that purpose and, after approval by the foremen, are collected each day by the timekeeper. The

Log of Well No. Property. Section No.

Graphic Log	From	To	Ft	Formation	From.	To.	Ft.	Formation	

Form 4. WELL LOG (*Back*)

timekeeper figures extensions and checks the time cards to see that each man has accounted for a full day. He then enters the time on the Pay Roll (Form No. 9) opposite name of employee and under proper day and enters total amount to Record of Time Cards (Form No. 11) under the corresponding day; then posts to column sheet for distribution of pay roll. The cards are then filed numerically by number of employee.

All time other than drillers, toolers and teamster is recorded

WESTERN OIL COMPANY.

DAILY REPORT OF WELLS PUMPED.

From 12 Noon. 19 To 12 Noon. 19

Property	Well No.	P.M.						Hours Idle.	Cause.	Rate in Seconds	A.M.						Hours Idle	Cause.	Rate in Seconds
		2	4	6	8	10	12				1	3	5	7	9	11			

This Report must be rendered daily.	Signed:
When Well is pumping mark 1	Pumper from 12 M to 12 P.M.
" " " idle " 0.	
Show condition every two hours.	Pumper from 12 P.M. to 12 M.

Form 5. DAILY REPORT OF WELLS PUMPED

on the General Time Card (Form No. 12). The same explanation holds good for operation as Drillers Time Card above.

Each teamster records his time on Teamster Time Card (Form No. 13) and enters thereon a description of the work done. Same explanation obtains for operation as Drillers Time Card above. The items are then posted to various accounts on distribution sheet and credited to Teaming Revenue, account No. 72. These charges are based on the prevailing teaming charges of the district.

Record of Pay Roll (Form No. 9) and Record of Time Cards (Form No. 11) are placed opposite each other in a loose-leaf binder.

WESTERN OIL COMPANY

Recapitulation of Oil Production for the Month of,– Tank No Property

	Day	Barrels Oil in Tank at Start	Run in Tank: Ticket No	Run in Tank: Barrels	Deductions: For Temperature	Deductions: For Specific Gravity	Deductions: For Water & Sand	Total Deductions	Net Crude Oil	Net Sales	Used for Fuel	In Tank at End: Barrels	In Tank at End: Amount

Form 6. RECAPITULATION OF OIL PRODUCTION

WESTERN OIL COMPANY. RUN TICKET.

________ 19__ No ________

Sold to, ________

From Tank No Run No.

	Description	No. Feet	No Inches	Detail Quantity	Total Quantity
	Gauge before Run				
	Gauge after Run				
	Gross No Barrels				
	Temperature				
	Spec Gravity				
	% Water and Sand				
	Total Deductions				
	Total Net Barrels Crude Oil				
	Total Charge @ per Bbl				Amount

Delivered by ________ Receipted for Purchaser by ________

Form 7. RUN TICKET

The time cards are posted each day to Record of Pay Roll for time of employee and Record of Time Cards (Form No. 11) for value of each employee's time. The total amount entered on this sheet for the day must agree with the Distribution of Pay Roll according

HIRING CARD WESTERN OIL Co

Date. ________ 19__

Name ________ No ________

Address ________

Nationality ________ Married or Single ________ Age ________

Last Occupation ________ Name of Employer ________

In what Capacity ________ How long Employed ________

Employed as	Location	Rate	Per	From

Left our Employ ________

Reason ________

Sign of Employe ________ Sign of Supt ________

Form 8. HIRING CARD

to accounts affected and should balance at the end of the month. At the end of the month, this total must equal the total amount as shown on Record of Pay Roll (Form No. 9) in column headed Amount Earned.

At the end of the month, totals as shown on Distribution of Pay Roll according to accounts affected and totals shown on Record of Pay Roll for amount earned, as well as details regarding deductions are entered on Pay-Roll Report (Form No. 26) which is sent to the main office.

WESTERN OIL COMPANY

Field Record of Pay Roll for Period begining, ______ 19 ___ Ending ______ 19 ___

Compiled by ______ Checked by ______ Approved by, ______

	No	Name	Occupation	1 15	2 17	3 18	4 19	5 20	6 21	7 22	8 23	9 24	10 25	11 26	12 27	13 28	14 29	15 30	31	Total Time	Rate	Amount Earned	Deductions Board	Rent	Misc'l	Field Pay't	Total Deductions	Balance Due	✓	Check No
		Amounts Forwarded																												

Form 9. RECORD OF PAY ROLL

DRILLING TIME CARD.
WESTERN OIL COMPANY.

Name ______ No. ______

Time, ______ Rate, ______ Amount. ______

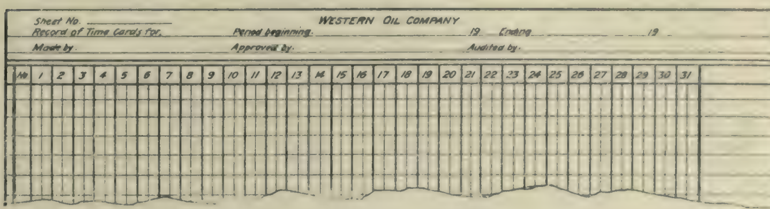
Work Done	Well No	Time	Amount.
Rigging Up			
Drilling			
Fishing			
Putting in Casing			

When roustabouts work on new well they must use this card

Write explanation of work done on back

Form 10. DRILLING TIME CARD

Upon receipt of copy of Pay-Roll Record (Form No. 9) at main office the Voucher Check is drawn for net amount of pay roll and charged to accrued pay-roll account No. 43. Pay checks (Form

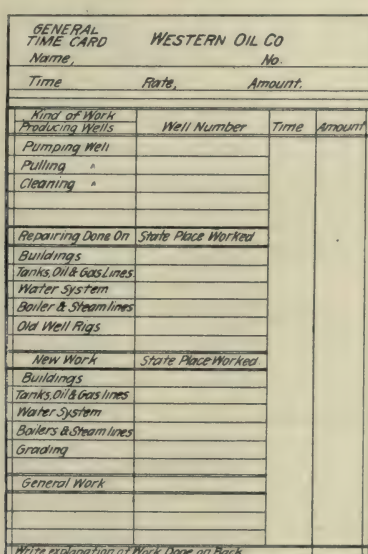

Sheet No.
WESTERN OIL COMPANY
Record of Time Cards for, Period beginning 19 Ending 19
Made by Approved by Audited by

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	

Form 11. RECORD OF TIME CARDS

No. 14) are then drawn for amount due each employee as shown on the Pay-Roll Record on which the number of pay check is noted. Pay checks are then sent to the field for distribution to employees.

When an employee is discharged the foreman or superintendent makes out a Discharge Card (Form No. 15) showing employee's name number, time discharged, hours worked and day discharged. The


GENERAL TIME CARD WESTERN OIL Co
Name, No.
Time Rate, Amount.

Kind of Work / Producing Wells	Well Number	Time	Amount
Pumping Well			
Pulling "			
Cleaning "			
Repairing Done On	State Place Worked		
Buildings			
Tanks, Oil & Gas Lines			
Water System			
Boiler & Steam lines			
Old Well Rigs			
New Work	State Place Worked		
Buildings			
Tanks, Oil & Gas lines			
Water System			
Boilers & Steam lines			
Grading			
General Work			
Write explanation of Work Done on Back			

Form 12. GENERAL TIME CARD

employee takes the discharge card to the timekeeper, who records thereon detailed information regarding time, deduction and balance due. The discharge card is signed by the employee and payment

TEAMSTERS TIME CARD. WESTERN OIL Co.
Name ______ No. ______
Date ______ Employe Rate ______ Amount

TEAMSTERS REPORT. Number of Animals Used. ______
Chargeable Rate. ______

Load of.	From.	To.	Time Started	Time Finish'd	Hours on Job.	Acc'ts Charg'd	Amount.

If Grading or Road Work, State fully work done and where.

The above is correct:
______ Head Teamster.

Form 13. TEAMSTER TIME CARD

Statement No. ______
From: ______
To. ______
Total Days: ______
At. $ ______
Deductions
Board, ______
Store, ______
Advances, ______
Total, ______
Balance due. ______

PAY CHECK

San Francisco, Cal. ______ 19__ No. ______

WESTERN OIL COMPANY

Pay to the Order of ______ $ ______

______ Dollars

In full for all Service to; ______

To
FIRST NATIONAL BANK,
San Francisco, California.

WESTERN OIL COMPANY.
By ______

Form 14. PAY CHECK

DISCHARGE CARD

WESTERN OIL COMPANY

Employe ______ No ______ Time Discharged, ______ Hrs Worked To day, ______

______ Superintendent - Foreman

From	To	Number of Days	Rate	Amount	Deductions Description	Deductions Amount	Balance Due

Paid by Check No. ______ | Date ______ | I hereby acknowledge receipt of payment for services in full as detailed above ______

Form 15. DISCHARGE CARD

made from Revolving Fund at Oil Fields, account No. 2. The cards are then filed alphabetically by employee's name.

Purchasing and Stores System. The main divisions of this system are as follows:

(a) Requisitions
(b) Purchasing
(c) Receiving
(d) Storing
(e) Issuing
(f) Transfers

All purchases, whether for oil-well material and supplies or commissary, are purchased by the purchasing agent who is at the main office. The only exception to the above is in case of a rush order, then the purchase order is sent direct from the field office.

Requisitions (Form No. 16) are made out in duplicate at the field for all purchases. The original is sent to the purchasing agent and a duplicate is retained for field record. Purchase Order (Form No. 17) is made out in triplicate. Original is sent to the individual or company from whom the purchase is made, duplicate is retained as a main-office record and the triplicate is mailed to the field for field record.

All invoices are received at the field in duplicate, and after goods have been received and invoices checked for quantity, prices, etc., the originals are forwarded to the purchasing agent. Duplicates are retained at the field and filed for reference. A properly arranged store-room is essential, and it should be laid out to insure a place for everything and everything in its place.

All stores, whether taken from oil-well materials and supplies or from commissary, are issued on a requisition (Form No. 18), and it must be shown on these requisitions whether materials given out are old or new. Stores transferred between wells or accounts, or coming from the field to the store-room are handled on Transfer Slips (Form No. 19). A Stock Ledger (Form No. 20) is kept for oil-well materials and supplies and also commissary. In the commissary only the portion designated as 'New Material' is used. Invoices as received at the field are checked for prices, quantities, extension, etc., and the distribution to the account affected is also shown thereon.

When all invoices have been properly checked they are posted to the Stock Ledger (Form No. 20), being entered as a charge to the article affected under the caption of New Material. Charges to Old Material are entered from the Transfer Slips (Form No. 19).

PURCHASE REQUISITION. WESTERN OIL COMPANY.
Purchasing Department Date, ________ 19____

Please order supplies, as follows.

On Hand.	Wanted.	Material.	Purpose

Approved

________ Field Manager. ________ Stores-Commisary Manager.

Form 16. PURCHASE REQUISITION

PURCHASE ORDER

WESTERN OIL Co. Date. ________ 19____ Put this No. ________ On Your Invoice.

To; ________

Gentlemen: Please furnish this Company the following goods. Ship to ________ Via. ________

	Quantity.	Machine or Part Number	Description.	Price.	Amount.

Send all Invoices to Field Office in Dupl. Also B/L. showing Weight and Rate. We pay no charges for packing or Draying.

Terms

WESTERN OIL COMPANY.
By: ________

Form 17. PURCHASE ORDER

STORE ROOM REQUISITION. WESTERN OIL COMPANY.

Date, ______________ 19 ____ No ________

Issued for. Acct No.

Charge Entered.

Quantity	Description	Price.	Old Material		New Material	

Delivered by:	Received by:	Signed by:

Form 18. STORE-ROOM REQUISITION

A store-room requisition (Form No. 18) is made out for all materials and supplies desired, and these requisitions must be signed by proper authority before being honored by the storekeeper. Each day the requisitions, together with all transfer slips, are sent to the accounting department at the field, and, after being checked, priced and extended are re-capped on sheets headed Re-cap of Stores Issued and Re-cap of Transfers respectively. They are then entered in the Stock Ledger (Form No. 20) as credits to the articles affected, and after

TRANSFER SLIP. WESTERN OIL COMPANY.

Slip No. ________

Make No Transfers Without Transfer Slip. Give full Information

Charge, ______________ Account No. ________

Credit, ______________ Account No. ________

Quantity.	Description	For Office Use Only.				
		Price	Old Material		New Material	

Delivered by:	Received by:	Authorized by:

Form 19. TRANSFER SLIPS

STOCK LEDGER. WESTERN OIL COMPANY.
Article. Sheet No.
Maximum. Minimum. Unit.

	New Material.								Old Material.							
	Quantities In.			Quantities Out			Balance.	✓	Quantities In			Quantities Out.			Balance	✓
	Purchase No.	Amount	✓	Req No	Amount	✓			Transfer No.	Amount.	✓	Req No	Amount	✓		

Form 20. STOCK LEDGER

having been proved with the daily total of distribution as shown on the two re-cap sheets are filed under date of issue.

After invoices have been properly recorded at the field they are sent to the main office and entered in the Purchase Ledger (Form No. 21) and also in the Distribution Ledger (Form No. 22). Invoices are first posted in the Purchase Ledger (Form No. 21) to the

PURCHASE LEDGER WESTERN OIL COMPANY. Control No
Sheet No. Name,
Terms, Address,
Remarks,

	Date of Entry	Description	Check No	Date of Invoice	Invoice No	Charges	✓	Credits	Balance	
									Kind	Amount

Form 21. PURCHASE LEDGER

account of the creditor and as they are posted, the control number and invoice number are entered thereon. They are next posted to the Distribution Ledger (Form No. 22) as a charge against the account affected. The 'reverse proof' posting system is used so that the total of all credits to the Purchase Ledger must agree with the total of all charges to Distribution Ledger.

DISTRIBUTON LEDGER WESTERN OIL COMPANY.
Account Account No. Sheet No

	Date	Control No	Invoice No.	Amount	Date	Control No	Invoice No	Amount	Date	Control No	Invoice No.	Amount

Form 22. DISTRIBUTION LEDGER

Machine Shop. All work performed by the machine shop must originate from a Work Order in duplicate (Form No. 23), original to accounting department, and duplicate to machine shop. Each Work Order is entered on a register showing the work order, date of work

WESTERN OIL Co

Work Order No.

Make for

Date,

To be completed

Ordered By,

Quantity	Articles	Particulars

Date Completed	Material			Total Cost	No. of Articles	Cost Each
	Labor					
Received, By.	Expense					
	Total.					

Form 23. WORK ORDER (*Front*)

order, made for, and date to be completed. The time of each employee in the machine shop is recorded daily on Machine Shop Time Card (Form 24). At the close of each day all time cards are sent to the timekeeper, who enters the employees' rate and extends the amount.

Materials for jobs are recorded on Machine Shop Material Requisition (Form No. 25), and each day they are sent to the stores department, where the prices are entered and amounts extended. After being priced and extended they are sent to the accounting department and with the time cards are re-capped daily, showing the charges to

Material			Labor			Labor.			Labor		
Date	Requisition No	Amount	Date	Employe No	Amount	Date	Employe No	Amount	Date	Employe No	Amount

Form 23. WORK ORDER (*Back*)

work orders affected. At the close of the month, from the recapitulation of time cards, and material requisitions, Work-in-Process (Account No. 16) is charged and Accrued Pay Roll (Account No. 43) and Oil-Well Material and Supplies (Account No. 11) respectively, are credited.

MACHINE SHOP TIME CARD — Employe No — WESTERN OIL Co

Name — Date

Work Done	Work Order Number	Hours Worked	For Office Use: Rate	For Office Use: Amount

Signed — Foreman

Form 24. MACHINE-SHOP TIME CARD

MACHINE SHOP MATERIAL REQUISITION. — WESTERN OIL Co.

Date, — Charge to Work Order No. — Requisition No.

Description.	Quantity.	For Office Use. Price.	For Office Use. Amount.

Form 25. MACHINE-SHOP MATERIAL REQUISITION

WESTERN OIL COMPANY

PAY ROLL REPORT.

Report of Pay Roll & Deductions for Month of, 19

Distribution of Pay Roll: Act No	Description	Amount.	Deductions: Act No.	Account	Amount
9	Wells Drilling,- See Analysis below				
10	Wells Completed,- " " "				
11	Oil Well Mat'l & Supplies.				
18	Buildings & Structures				
19	Oil System				
20	Gas "				
21	Water "				
22	Steam "				
23	Fire "				
24	Electr & Teleph System				
25	Graded Roads & Grounds				
32	Advanced Expenses				
110	Pumping				
111	Pulling				
112	Cleaning				
113	Repairing				
117	Maint & Repairs,- Bldgs & Structures				
118	" " " - Oil System				
119	" " " - Elect & Tel System				
120	" " " - Fire System				
121	" " " - Graded Roads & Grds				
12E	Commisary				
13D	Boarding House				
14A	Teaming				
76B	Drilling & Field Tools Expense.				
79C	Water System Expense				
82A	Steam " "				
88A	Gas " "				
16A	Machine Shop "				
91	Administration & Office				
92	Superintendence				
	Credit Accrued Pay Roll Acct Nº 43			Charge Accrued Pay Roll Acct Nº 43	

Analysis of Account Nº 9: Well Nº	Section Nº	Amount	Analysis of Account Nº 10: Well Nº	Section Nº	Amount	Remarks

Form 26. PAY-ROLL REPORT

OIL WELL MATERIALS & SUPPLIES REPORT. WESTERN OIL COMPANY.

Report of Supplies Issued & Transfers Made for Month of, 19 .

	Acc't No	Description	From Oil Well Mat'l & Supplies Acc't No 11	From Transfers: Charges	From Transfers: Credits
	9	Wells Drilling,-See Analysis below.			
	10	" Completed,- " " "			
	11	Oil Well Material & Supplies.			
	18	Buildings & Structures			
	19	Oil System.			
	20	Gas "			
	21	Water "			
	22	Steam "			
	23	Fire "			
	24	Electric & Telephone System			
	25	Graded Roads & Grounds			
	32	Advanced Expenses.			
	110	Pumping.			
	111	Pulling.			
	112	Cleaning.			
	113	Repairing			
	117	Maintenance & Repairs - Buildings & Structures.			
	118	" " " - Oil System.			
	119	" " " - Electric & Telephone System.			
	120	" " " - Fire System.			
	121	" " " - Graded Roads & Grounds.			
	14E	Teaming Expense.			
	76A	Drillig & Field Tool Expense			
	79D	Water System Expense.			
	82D	Steam " "			
	16B	Machine Shop "			
	88B	Gas System "			
		Credit Oil Well Material & Supplies Acc't No 11.			

	Analysis of Wells Drilling - Account No 9.					Analysis of Wells Completed,-Account No 10				
	Well No	Section No	Amount	From Transfers: Charges	From Transfers: Credits	Well No	Section No	Amount	From Transfers: Charges	From Transfers: Credits

Form 27. OIL-WELL MATERIAL AND SUPPLIES REPORT

After the time cards and material requisitions have been re-capped they are posted to each work order showing date, requisition number and amount for material used, and date, employee number and amount for labor charges. This information is not shown on the duplicate sent to the machine shop, as the copy sent to machine shop is for instructions only. Completed work orders are re-capped at the close of the month and charged to accounts affected, as shown on the work orders, and machine shop (Account No. 84) is credited. From the total of cost of completed orders a charge is made to Cost of Machine Shop Revenue (Account No. 85). Work in Process (Account No. 16) is credited. This latter account will then show at the close of each month the value of uncompleted orders.

Reports. The following reports are received from the field at the close of each month, and from these reports postings are made to the general records:

TEAMING REPORT — WESTERN OIL COMPANY

Record of Teaming Charges for Month of ________ 19 __

Acc't No	Accounts	Amount	Analysis of Wells Drilling, Acc't No 9		Amount
9	Wells Drilling - See Analysis		Well	Section	
10	" Completed - " "		"	"	
11	Oil Well Material & Supplies		"	"	
18	Buildings & Structures.		"	"	
19	Oil System		"	"	
20	Gas "		"	"	
21	Water "		"	"	
22	Steam "				
23	Fire "				
24	Electr & Teleph System.				
25	Graded Roads & Grounds				
32	Advanced Expenses				
110	Pumping				
111	Pulling				
112	Cleaning				
113	Repairing				
117	Maintenance & Repairs,-Bldgs & Structr's				
118	" " " - Oil System.				
119	" " " -Elec & Tel "				
120	" " " - Fire "				
121	" " " -Graded Roads etc				
12C	Commissary				
13E	Boarding Houses.				
14B	Teaming				
76C	Drilling & Field Tools Expense				
79G	Water System Expense				
82E	Steam " "		Analysis of Wells Completed, Acc't No 10		Amount
16G	Machine Shop "		Well	Section	
88D	Gas System "		"	"	
127	Operations.		"	"	
92	Superintendence.		"	"	
	Credit Teaming Revenue Acc't. 72		"	"	
Remarks.			"	"	
			"	"	

Form 28. TEAMING REPORT

MACHINE SHOP REPORT — WESTERN OIL COMPANY.

Report of Machine Shop Operations for Month of ________ 19 __

Acc't No.	Description.	Amount.	Analysis of Machine Shop Cost: Labor	Material	Expense	Total Cost	Remarks
9	Wells Drilling - See Analysis below						
10	Wells Completed - " " "						
11	Oil Well Material & Supplies.						
18	Buildings & Structures.						
19	Oil System.						
20	Gas "						
21	Water "						
22	Steam "						
23	Electric & Telephone System						
24	Fire System.						
25	Graded Roads & Grounds						
32	Advanced Expenses						
110	Pumping.						
111	Pulling						
112	Cleaning.						
113	Repairing.						
117	Maintenance & Repairs - Bldgs & Structrs						
118	" " " - Oil System.						
119	" " " - Elect & Tel Sys						
120	" " " - Fire System						
121	" " " - Graded Roads, etc.						
12 E	Commisary						
13 D	Boarding Houses						
14 A	Teaming						
76 B	Drilling & Field Tool Expense						
79 C	Water System Expense.						
82 A	Steam " "						
88 A	Gas " "						
16 E	Machine Shop, Maint. & Repairs						
91	Administration & Office						
92	Superintendence						
	Credit Machine Shop Revenue Acct No 84.						

Analysis of Account-9			Analysis of Account-10.			General Remarks
Well No	Section No	Amount	Well No	Section No	Amount.	

Form 29. MACHINE-SHOP REPORT

Pay-Roll Report (Form No. 26). As described in the Pay-Roll system, this report is made up from the several Pay-Roll records. Upon receipt of same at main office the information contained thereon is posted to the General Records, charging accounts Nos. 9 to 92 inclusive, in accordance with the classification, and crediting total to Accrued Pay Roll (Account No. 43). Accrued Pay Roll (Account No. 43) is

WESTERN OIL COMPANY.

Report of Water, Gas & Steam Systems, Drilling & Field Tools Revenues, Month of. 19 .

Acct. Nº	Report of Water System Revenues. Description.	Amount.	Acct. Nº	Report of Gas System Revenues. Description.	Amount.
6	Accounts Receivable.		6	Accounts Receivable	
13E	Boarding Houses.		13E	Boarding Houses	
16G	Machine Shop.		95	General Expenses.	
76E	Drilling & Field Tool Expense.		124	Operations.	
82C	Steam System.				
95	General Expenses.				
121	Maint. & Repairs,-Graded Roads & Grds.				
125	Operations.				
	Credit Water System Revenue Acct. 78.			Credit Gas System Revenue.-Acct. 87.	
	Analysis of Accts. Receivable Acct. 6.			Analysis of Accts Receivable-Acct. 6.	
	Name.			Name	
	Total.			Total	

Report of Drilling & Field Tool Revenues						Report of Steam System Revenues					
Well No	Section Nº	Amount	Well Nº	Section Nº	Amount.	Well Nº.	Section Nº	Amount.	Well Nº.	Section Nº	Amount.
						Charge Wells Drilling Acct. 9.					
				Total		Charge Operations " 126.					
Charge Wells Drilling Acct. 9-Credit Drill. & Field Tool Rev. Ac. 75.						Credit Steam System Revenue Acct. 81. Total					
Remarks:											

Form 30. REPORT OF WATER, GAS, STEAM AND DRILLING AND FIELD REVENUES

charged and the different accounts affected by pay-roll deductions are credited with the respective amounts of deductions.

For further information and to show the amounts affecting each drilling well, as well as each completed well, a detailed analysis is shown at the bottom of the report. Under each division the analysis gives the well number, section and amount chargeable to each well.

Oil-Well Material and Supplies Report (Form No. 27). The general principle of handling the pay-roll report as outlined above is used

CASING REPORT WESTERN OIL COMPANY

Record of Casing Used Month of 19

	Well No	Well Sec	Number of Feet	Size	Weight	Cost per Foot	Total Charges	✓	Remarks
	Total								

Record of Casing Returned Month of 19

	Well No	Well Sec	Number of Feet	Size	Weight	Cost per Foot	Total Charges	✓	Remarks
	Total								

	Summary		Feet	Amount		Remarks
	Casing in Wells First of Month					
	Casing used during Month					
	Total					
	Casing Returned during Month					
	Casing in Wells at Date ( )					

Form 31. CASING REPORT

PRODUCTION REPORT WESTERN OIL COMPANY

Record of Oil Production for Month of 19

	Well No	Total Bbls for Month	Per Cent of Month Operating	Total Hours Producing	Per Cent of Time Producing	Average Bbls per day of 24 Hours	Remarks
	Totals						

	Summary	Details	Totals	
	In Storage First of Month			
	Production during Month			
	Less Lease Consumption			
	In Storage First of Month & Produced during Month			
	Less Shipments during Month			
	In Storage at Date (			

Form 32. PRODUCTION REPORT

OIL SALES REPORT WESTERN OIL COMPANY

Record of Oil Sold & Used for Fuel,- Month of, 19

	Acct No	Account	Barrels	@ per Bbl	Amount	Analysis of Wells Drilling [illegible]					
	6	Accounts Receivable (See Analysis)									
	"	Wells Drilling - (" ")									
	76 D	Drilling & Field Tool Expense									
	79 E	Water System									
	82 B	Steam "									
	16 C	Machine Shop									
	121	Maint & Repairs,-Graded Roads; Grounds									
		Credit Oil Sales Acct. No 60.									

Analysis of Oil Sales - Accounts Receivable,- Month of, 19

	Name	Barrels.	@ per Bbl	Amount	Name	Barrels	@ per Bbl	Amount
	Carried Forward.				Total			

Form 33. OIL-SALES REPORT

in handling this report. The accounts affected in the classification are charged and Oil-Well Materials and Supplies (Account No. 11) is credited with the total issues for the month as shown by the material requisitions. From the recapitulation of Transfer Slips (Form No. 19) accounts are charged with the total received through transfers and credited with the total issued through transfers.

Account No. 11 will show charges for all materials going back into stock from the field. Wells drilling and completed wells show by individual wells a complete analysis of charges from Account No. 11 as well as charges and credits through transfer to or from other accounts.

Teaming Report (Form No. 28). This report shows the total monthly earnings from team operations and from the report the respective accounts are charged and Teaming Revenue (Account No. 72) is credited. The revenue arises from charges for the use of teams at going rates. All expenses of operating the teams are charged to team-

WESTERN OIL COMPANY.

Comparative Statement of Assets; Liabilities & Capital Worth for Period ending, 19

	Title of Accounts.	This Year		Last Year		
	ASSETS	Detail	Total.	Detail	Total.	
	CASH ASSETS.					
1	Revolving Fund - San Francisco.					
2	" " Oil Fields					
3	First National Bank - San Francisco.					
4	" " " " - Bakersfield					
5	Traveling Funds					
	CURRENT ASSETS.					
6	Accounts Receivable.					
7	Loans & Notes Receivable.					
8	Personal Accounts.					
	WELL DEVELOPMENT ASSETS.					
9	Wells Drilling - (See Analysis.)					
10	" Completed - (See Analysis)					
	INVENTORY ASSETS.					
11	Oil Well Material & Supplies.					
12	Commissary.					
13	Boarding Houses.					
14	Hay, Grain & Feed.					
15	Oil on Hand.					
16	Machine Shop - Work in Progress					
	PLANT ASSETS.					
17	Lands.					
18.	Leases.					
19	Buildings & Structures.					
20	Oil System					
21	Gas "					
22	Water "					
23	Steam "					
24	Fire "					
25	Electr. & Teleph. System.					
26	Graded Roads & Grounds.					
	EQUIPMENT ASSETS.					
27	Horses, Wagons & Harness.					
28	Furniture & Fixtures, - General.					
29	Office Equipment.					
30	Drilling & Field Tools.					
31	Shop Machinery and Tools.					
32	Commissary Equipment					
	DEFERRED ASSETS.					
33	Advanced Expenses.					
34	Unexpired Insurance.					
35	" Taxes.					
36	Stationery & Office Supplies.					
	Total Assets.					
	LIABILITIES.					
	CURRENT LIABILITIES.					
40	Accounts Payable.					
41	Loans & Notes Payable.					
42	Accrued Expenses					
43	" Pay Roll.					
	RESERVE LIABILITIES.					
44	Reserve for Depreciation - Exhaustion of Oil Lands.					
45	" " " - Wells.					
46	" " " - Plant.					
47	" " " - Equipment					
48	" " Extraordinary Losses & Expense.					
	Total Liabilities					
	CAPITAL WORTH.					
49	Authorized Capital Stock.					
50	Less Unsubscribed Capital Stock					
	Net Capital Stock Issued					
51	Surplus Adjustment.					
52	" At Date.					
	Total Liabilities & Capital Worth.					

Form 34. COMPARATIVE STATEMENT OF ASSETS, LIABILITIES AND CAPITAL WORTH

ing under the proper classification and by crediting teaming revenue with the use of teams at going rates it enables the company to determine whether it is better to operate their own teams or hire outside teaming.

As provided in the previous reports, the individual drilling wells and completed wells share the respective charges for teaming service.

Machine Shop Report (Form No. 29). This report is made up from the recapitulation of completed orders. The respective accounts

WESTERN OIL COMPANY

Comparative Statement of Revenues & Expenses for Month of 19

	Acct No	Description	This Year Current Month	This Year Mo to Date	Last Year Current Month	Last Year Mo to Date
	60	Oil Sales				
	61	Cost of Oil Sold				
		Gross Gain				
	63	Oil Well Materials & Supplies Sales				
	64	Cost of Oil Well Materials & Supplies Sold & Issued				
		Gross Gain				
	66	Commissary Sales				
	67	Cost of Commissary Sales & Issues				
		Gross Gain				
	69	Boarding House Revenue				
	70	Cost of Operating Boarding Houses				
		Gross Gain				
	72	Teaming Revenue				
	73	Cost of Operating Teams				
		Gross Gain				
	75	Drilling & Field Tool Revenue				
	76	Drilling & Field Tool Expense				
		Gross Gain				
	78	Water System Revenue				
	79	Cost of Operating Water System				
		Gross Gain				
	81	Steam System Revenue				
	82	Cost of Operating Steam System				
		Gross Gain				
	84	Machine Shop Revenue				
	85	Cost of Machine Shop Revenue				
		Gross Gain				
	87	Gas System Revenue.				
	88	Cost of Operating Gas System				
		Gross Gain				
		Total Gross Gain.				
		GENERAL EXPENSES				
	91	Administrative & Office Salaries				
	92	Superintendence				
	93	Office Expenses				
	94	Stationery & Office Supplies				
	95	Other General Expenses				
	96	Insurance				
	97	Taxes				
	98	Rents				
	99	Telephone & Telegraph				
	100	Traveling Expenses				
	101	Commissions				
	102	Legal Expenses				
		Total General Expenses.				
		Less __% Charged to Production				
		Less __% Charged to Operating				
		Total Deductions.				
		Net General Expenses.				
		Net Operating Gain.				
		MISCELLANEOUS GAINS & LOSSES.				
	104	Miscellaneous Gains				
	105	Discount Received.				
	106	Interest Received				
		Total				
	107	Miscellaneous Losses.				
	108	Discount Allowed.				
	109	Interest Paid				
		Total.				
		Net Miscellaneous Gain-Loss				
	52	Net Gain for Period.				
	52	Surplus First of Period				
	52	Surplus At Date				

Form 35. COMPARATIVE STATEMENT OF REVENUES AND EXPENSES

affected are charged and Machine Shop Revenue (Account No. 84) is credited with the total.

There is also shown on this report an analysis of labor, material and expense on completed orders. The total of this represents the cost of completed orders and from this information Cost of Machine Shop Revenue (Account No. 85) is charged and Machine Shop-Work in Process (Account No. 16) is credited.

Report of Water System Revenues.
Report of Gas System Revenues.
Report of Steam System Revenues.
Report of Drilling and Field Tool Revenues.
} Form No. 30.

WESTERN OIL COMPANY

Analysis of Production & Operating Costs for Month of 19

Acct Nº	Description	This Year Current Month	This Year — Mo to Date	Last Year Current Month	Last Year — Mo to Date	
	PRODUCTION COST					
	DIRECT					
110	Pumping					
111	Pulling					
112	Cleaning					
113	Repairing					
114	General Expenses —%					
	Total Direct Cost					
	INDIRECT					
115	Depreciation – Exhaustion of Oil Lands					
116	" - of Wells					
	Total Indirect Cost					
	Total Production Cost					
	OPERATING COST					
117	Maintenance & Repairs - Buildings & Structures					
118	" " " - Oil System					
119	" " " - Electric & Telephone System					
120	" " " - Fire System					
121	" " " - Graded Roads & Grounds					
122	" " " - Furniture & Fixtures					
123	" " " - Office Equipment					
124	Gas System Charges					
125	Water " "					
126	Steam " "					
127	Teaming "					
128	Depreciation - General					
129	Extraordinary Losses & Expenses					
130	Royalties					
131	General Expenses —%					
	Total Operating Cost					
	Less —% Charged to Development					
	Net Operating Cost					
	Total Cost of Months Production					
15	Oil on Hand - First of Period					
	Total Cost - Oil on Hand First of Period & Produced					
	" " - Oil Sold and Consumed					
15	Value of Oil on Hand - End of Period					
	Barrels of Oil on Hand - End of Period					
	Cost per Barrel - Direct Production					
	" " " - Inderect "					
	" " " - Operating					
	Total Cost per Barrel					

ANALYSIS OF WELLS DEVELOPMENT – WELLS DRILLING ACCOUNT Nº 9

Well Nº	Section Nº	Previously Expended Ft Drilled	Previously Expended Amount	Previously Expended Cost pr Ft	Expended this Month Ft Drilled	Expended this Month Amount	Expended this Month Cost pr Ft	Expended to Date Ft Drilled	Expended to Date Amount	Expended to Date Cost pr Ft	

Form 36. COMPARATIVE ANALYSIS OF PRODUCTION AND OPERATING COSTS

The information for these reports is consolidated on one sheet and, as in the case of the previous reports, the accounts affected are charged and the respective revenue accounts are credited. The information compiled on this report is obtained from recapitulation of the details of operation. Going rates for charges for water, gas, steam and the use of drilling and field tools are established and upon these rates is determined the revenue earned.

Casing Report (Form No. 31). A detailed record is kept of all casing issued out of stock as well as all casing received back into stock

WESTERN OIL COMPANY.

Comparative Analysis of Dept. Operations for Month of ______ 19__

Acct. No.	Description	This Year: Current Month	This Year: Mo. to Date	Last Year: Current Month	Last Year: Mo. to Date
	ANALYSIS OF OIL WELL MATERIAL & SUPPLIES				
11	Inventory First Period				
A	Purchases				
B	Freight				
C	Teaming Charges				
D	Expenses				
E	Labor				
	Total Charges				
11	Inventory End of Period				
G	Cost of Sales & Issues				
	ANALYSIS OF COMMISSARY				
12	Inventory First of Period				
A	Purchases				
B	Freight				
C	Teaming Charges				
D	Expenses				
E	Labor				
	Total Charges				
12	Inventory - End of Period				
G	Cost of Commissary Sales & Issues				
	ANALYSIS OF BOARDING HOUSES				
13	Inventory - First of Period				
A	Meats				
B	Groceries				
C	Supplies				
D	Labor				
E	Other Expenses				
G	Depreciation				
	Total Charges				
13	Inventory - End of Period				
H	Cost of Operating Boarding Houses				
	ANALYSIS OF TEAMING				
14	Inventory - First of Period				
A	Labor				
B	Hay Grain & Feed				
C	Shoeing				
D	Veterinary				
E	Repairs to Equipment				
G	Depreciation				
H	Hired Teams				
	Total Charges				
14	Inventory - End of Period				
J	Cost of Operating Teams				
	ANALYSIS OF MACHINE SHOP				
16	Work in Progress - First of Period				
A	Labor				
B	Material				
C	Fuel				
D	Power				
E	Maintenance & Repairs				
G	Other Expenses				
H	Depreciation				
	Total Charges				
16	Work in Progress - End of Period				
J	Cost of Completed Orders				
76	ANALYSIS OF DRILLING & FIELD TOOL EXPENSE				
A	Material & Supplies				
B	Labor on Repairs to Apparatus				
C	Other Expenses				
D	Fuel				
E	Water				
G	Depreciation				
76	Total Drilling & Field Tool Expense				
79	ANALYSIS OF WATER SYSTEM				
A	Purchases of Water				
B	Freight on Water Purchased				
C	Labor Pumping or Producing				
D	Material used for Producing				
E	Fuel				
G	Maintenance & Repair				
H	Depreciation				
79	Cost of Operating Water System				
82	ANALYSIS OF STEAM SYSTEM				
A	Labor				
B	Fuel				
C	Water				
D	Supplies				
E	Other Expenses				
G	Maintenance & Repairs				
H	Depreciation				
82	Cost of Operating Steam System.				
88	ANALYSIS OF GAS SYSTEM				
A	Labor				
B	Supplies				
C	Maintenance & Repairs				
D	Other Expenses				
E	Depreciation				
88	Cost of Operating Gas System				

Form 37. COMPARATIVE ANALYSIS OF DEPARTMENTAL OPERATIONS

and at the end of the month a casing report is made up showing the complete transactions by wells. From the report (Account No. 9) Well Drilling is charged and Casing, under Account No. 11, is credited with all casing issued. A contra entry is made for all casing received back into stock. The individual well accounts are charged and credited in accordance with the classification.

Production Report (Form No. 32). This report is self-explanatory and it is only necessary to add that no closing entries are made therefrom, as it is for statistical purposes only.

Oil Sales Report (Form No. 33). From this report, an entry is made at the close of each month charging the respective accounts with the oil sold as enumerated in the classification and crediting (Account No. 60). A detailed list of account receivable sales is shown at the bottom of the report. The total of this list must agree with the total as represented by Account No. 6 at the top of the report. An analysis of charges to individual wells is also shown.

Financial Statements. Reports should be sent from the field to the main office, and must cover every operation, so that when received, the information can be posted direct to the general records without the necessity of voluminous correspondence in order to receive enlightenment upon certain subjects. The records at the main office should be so arranged that with very little effort an intelligent financial statement can be abstracted therefrom. These statements represent in terse form the complete operations and should consist of the following:

(a) Comparative statement of assets, liabilities and capital worth (Form No. 34)

(b) Comparative statement of revenues and expenses (Form No. 35)

(c) Comparative analysis of production and operating costs (Form No. 36)

(d) Comparative analysis of departmental operations (Form No. 37)

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